THE ANTARCTIC MANUAL

FOR THE

USE OF THE EXPEDITION OF 1901

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EDITED BY

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KEEPER OF BOTANY, BRITISH MUSEUM;
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WITH A PREFACE BY

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PRESIDENT OF THE ROYAL GEOGRAPHICAL SOCIETY

Presented to the Expedition and issued by the Royal Geographical Society

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Wolcott fund.

To

SIR JOSEPH DALTON HOOKER

G.C.S.I. C.B. D.C.L. LL.D. F.R.S.

THE LAST SURVIVING MEMBER OF

THE EXPEDITION OF THE 'EREBUS' AND 'TERROR'

INTO THE ANTARCTIC

PREFACE.

In 1874 I suggested that instructions and memoirs on the various scientific subjects which were to occupy the attention of the officers of the Arctic Expedition should be prepared, so as to form a manual. The biology, botany, geology, mineralogy and physics formed one volume, edited by Professor Rupert Jones, and printed at the expense of the Government. Some of the papers it contained are reprinted here, viz., those by Lord Kelvin and Professor Judd. The geography and ethnology formed another volume, edited by myself, which was printed at the expense of the Royal Geographical Society.

These Arctic manuals served their purpose, by giving easy access to information, otherwise inaccessible, which was required by the officers in their scientific investigations. Nor did their usefulness cease with the return of the expedition. They have been sought after and valued by subsequent Arctic explorers. Baron Nordenskjöld has told me that, during the voyage of the *Vega*, when the North-East Passage was discovered, the books most in request were the "blue book" and the "white book," as they called the Arctic manuals.

I was convinced that an 'Antarctic Manual' for the Expedition of 1901 would be even more useful, if prepared with the same object in view and on similar lines.

In November 1900 I was so fortunate as to secure the services of Mr. George Murray, as editor of such a manual. Mr. Murray entered fully into the spirit of my plan, arranged the subjects that would require treatment, obtained the services of the eminent men of science who have contributed, and has edited the whole work.

In accordance with the plan, the manual consists of instructions and of memoirs containing information. In the instructions are included the Astronomical Data, and the papers on Tidal, Wave, Ice and Pendulum Observations, on Terrestrial Magnetism, Climate, the Aurora, Atmospheric Electricity, Geology, Volcanic Action, and Rock Collecting, and Botany. But these instructions include much suggestive information. Especially is this the case in Dr. Blanford's paper on Antarctic Geology.

In his Chemical and Physical Notes Mr. Buchanan properly assumes a due knowledge of routine operations on the part of the physicist. He therefore furnishes him, and the other observers, with "observations by the way," as he calls the exceedingly valuable information and suggestions contained in his paper. It would not be easy to exaggerate the value of Mr. Buchanan's contribution.

The biological papers on the Whales, by Dr. Lydekker; on the Seals, by Mr. Barrett-Hamilton; on the Antarctic Birds, by Mr. Howard Saunders; on Deep-Sea Fishes, by Mr. Boulenger; on the Abysmal Fauna, by Mr. Arthur Shipley; and on the Zoology of Kerguelen, by Professor D'Arcy Thompson, are most interesting, and will be of almost daily use to the officers of the Expedition. There is also a valuable paper on Sledge Travelling, by Sir Leopold M'Clintock.

In the Geographical Section, the narratives of Antarctic voyages will be found, which would be otherwise inaccessible, either from being buried in voluminous works on other subjects, or in series of proceedings, or from having hitherto remained in manuscript. To the former category belong the narratives of Balleny, Dumont d'Urville and Wilkes; in the latter are included the exceedingly interesting narrative of Captain Biscoe, and the log of Balleny's mate, printed from manuscripts presented to the Royal Geographical Society many years ago by Mr. Charles Enderby. The narratives of Ross and Weddell are contained in volumes of convenient size, which are supplied to the Expedition. The section also contains a paper on the Exploration of Antarctic Lands, by M. Arçtowski; and one, by Mr. Bernacchi, on the Topography of South Victoria Land.

The Antarctic maps, accompanying the Manual, have been compiled with great care by Mr. Batchelor, under my superintendence.

The Manual concludes with an exhaustive Antarctic Bibliography, by Dr. Mill.

The 'Antarctic Manual' is presented to the Expedition by the President and Council of the Royal Geographical Society; and is also issued to Fellows as a supplementary volume.

The Editor, Mr. George Murray, to whom the Expedition already owes so much, goes out as Director of the Civilian Scientific Staff. No polar vessel ever left these shores so well adapted and prepared as the *Discovery*, to secure the valuable scientific results that are hoped from the exertions of the explorers; and I trust that one useful aid to our gallant friends, when in the far South, will be Mr. George Murray's 'Antarctic Manual.'

CLEMENTS R. MARKHAM.

July 1901.

PREFACE BY THE EDITOR.

I desire to thank all the contributors to the 'Antarctic Manual' gratefully for the invariable kindness and courtesy with which they have assisted in its production. My special thanks are due to Miss Ethel S. Barton, for her spirited translation of the narrative of Dumont d'Urville, and to Miss Eleanor P. Whitting for her devoted attention in reading the proofs of the Manual from cover to cover.

For its imperfections I can plead only one excuse, viz. the interference caused by the other preparations for the Expedition, and by my ordinary official duties.

GEORGE MURRAY.

London: *July* 1901.

CONTENTS.

MAPS.

ICE NOMENCLATURE.

BY

SIR CLEMENTS R. MARKHAM, K.C.B. F.R.S., AND

HUGH ROBERT MILL, D.Sc. LL.D.

Ablation.—Surface waste of ice or snow by melting or evaporation.

Anchor Ice = ground-ice.

Åser.—Ridges of stone or gravel believed to have been formed by glacial action. *See* **Esker.**

Avalanche.—A mass of snow, névé, or ice detached from its position, and slipping down a slope.

Barrier.—*See* **Ice Cliff or Barrier.**

Bay Floe.—A floe newly formed.

Bay Ice.—The young ice which first forms on the surface of the sea in autumn.

Bergschrund.—The wide crevasse usually found at the line where a glacier touches the solid rock of a mountain slope.

Beset.—The situation of a ship when closely surrounded by ice.

Bight.—An indentation in a floe of ice (like a bay).

Blink.—ICE BLINK.—A peculiar brightness along the horizon, which shows itself over a distant ice field. The blink over large quantities of ice and over land is yellowish.

WATER SKY is a blue streak on the horizon, denoting open water.

Bore.—The operation of boring through ice consists of entering it under press of sail or steam, and forcing the ship through by separating the masses.

Boulder Clay.—*See* **Till.**

Brash Ice.—Small fragments and nodules, the wreck of other kinds of ice.

Calf.—A mass of ice lying under a floe near its margin, and, when disengaged from that position, rising with violence to the surface.

Calving (of icebergs).—When a large or small block of ice breaks off from a parent ice-berg. The word may also be applied to an iceberg breaking off from a glacier.

Chinese Walls.—The continuous cliff in which some glaciers or ice sheets terminate when their bases are washed by the sea.

Crevasse.—A crack or rift in a glacier or ice-sheet.

Drift.—A vague geological term, inclusive of superficial detrital materials, coarse or fine, deposited by water, ice, or wind—more commonly the former.

Drift Ice.—Pieces smaller than a floe.

Drumlin.—A large flat mound of gravel or sand formed by glacial action.

Erratic Blocks.—Often now written simply "erratics." Portions of rocks, usually ice-worn, which have been transported by ice from their original position.

Eskers.—Long mounds or ridges, sometimes resembling moraines, or even railway embankments in general aspect, composed mostly of gravel, with more or less stratification, the layers often having some relation to the outer surface.

Field Ice = Ice-field.—A sheet of ice of such extent that its termination cannot be seen from the crow's nest.

Firn.—*See* **Névé.**

Floe.—The same as a field, except that its extent can be made out from the crow's nest.

Floeberg.—Large masses of sea ice, broken off from ancient floes of great thickness, when they are forced upon the shore.

Glaciation.—The action of a glacier or ice-sheet on the rocks or the country over which it has passed.

Glacier.—A river of solid ice, descending from its source in the high névé of a snowfield.

Glacière.—A cave containing ice all the year round.

Glacier-table.—A block of stone supported on a pedestal of ice on the surface of a glacier.

Ground Ice.—Ice formed on the bed of a river, lake, or shallow sea, while the water as a whole remains unfrozen.

Ground Moraine.—Term applied to detrital material travelling—sometimes, perhaps, accumulated—between a glacier or ice-sheet and the bed of rock below.

Hole.—A small pool of water in the ice.

Hummock.—A rough hillock of ice, whether formed by séracs, pressure ridges, or otherwise.

Iceberg.—A mass of land ice, broken from a glacier and floating in the sea.

Ice Blink.—The whitish glare in the sky over ice which is too far distant to be visible. *See* **Blink.**

Ice Block.—Dam formed across a river by the packing of masses of ice in spring.

Ice Cap.—A continuous covering of ice, névé, or snow, such as occurs in Polar lands.

Ice Cliff or Barrier.—The edge of the great Antarctic glaciers which enter the sea, but remain attached to the land.

Ice Fall.—An interruption in a glacier caused by an abrupt change of slope in its bed.

Ice Floe.—*See* **Floe.**

Ice Foot along a coast is caused by the accumulation of the autumn snow-fall as it drifts to the beach, being met by sea-water with a temperature just below the freezing-point of fresh water. It is at once converted into ice, forming a solid wall from the bottom of the sea, constantly maintained. The upper surface of an ice foot is level with the top of high water. The terrace above this wall, from its edge to the base of the talus, has a width dependent on the land slope.

Inland Ice.—An ice cap of very great extent, as in Greenland.

Kame.—A gravel ridge, similar to, or identical with an **Esker** (*which see*).

Land Ice.—Ice attached to the land, either in floes or in heavy grounded masses lying near the shore.

Lane.—A narrow track of open water between portions of pack ice or floes.

Lateral Moraine.—A ridge of rock débris along the side of a glacier.

Lead.—A lane or channel of open water through the ice.

Medial Moraine.—A ridge of rock débris running more or less along the middle line of a glacier.

Moraine.—Rock débris associated with a glacier.

Moulin (or **Glacier Mill**).—A vertical hole through the ice of a glacier down which a stream of water pours.

Névé = firn.—The upper portion of a glacier, the top layers of which are more nearly in the condition of snow, and in the whole of which much air is mingled with the ice—i.e. it is rather frozen snow, though often hard frozen, than true ice.

Nip.—The situation of a ship when forcibly pressed by ice on both sides. She is then said to be nipped.

Nunatak.—A rocky hill, generally glaciated, projecting from an ice sheet, or from an inland ice.

Pack.—A body of drift ice consisting of separate pieces, and the extent of which cannot be seen.
Open Pack.—When the pieces do not touch.
Close Pack.—When the pieces are pressed together.

Pack Ice.—The broken ice of floes driven together by wind and currents.

Palæocrystic Sea.—The mass of ancient floe ice packed against the land to the north of Greenland.

Pancake Ice consists of small circular pieces with raised edges. In a ruffled sea the pieces of bay ice strike each other on every side, and so become rounded with the edges turned up.

Patch.—A collection of drift ice, the limits of which are visible, in contradistinction to pack ice.

Pelagic.—Pertaining to the open ocean; removed from land influences.

Penitentes = Séracs on Andes glaciers.

Penknife Ice.—Described by Parry in his attempt to go north from Spitzbergen in 1827. In drained-off pools on the ice a columnar structure is left, the columns being 6 inches high, increasing in July to 18 inches. When stratification of snow covering a floe is exposed by a newly-formed crack, the lower portion granulates, the grains collecting together perpendicularly and leaving intermediate air spaces. This Parry called penknife ice.

Perched Blocks.—Boulders, usually glaciated, perched on other stones, as a result of ice action.

Regelation.—The freezing together of portions of ice which have been broken up.

Roche moutonnée.—A boulder or portion of rock which has been rounded and smoothed by glaciation.

Rotten Ice.—Old ice, partially melted, and in part honeycombed.

Sailing Ice.—Ice of which the pieces are so separated as to allow of a ship sailing among them.

Sallying a ship. Causing her to roll by the men running in a body from side to side, so as to relieve her from adhesion of young ice around her.

Séracs.—Sharp irregular ridges or pinnacles of ice, formed in a glacier where there is a sudden change in the slope of the bed too slight to produce an ice-fall.

Shearing Plane (the usual sense of the word).—A plane along which the particles on either side undergo a displacement parallel with it.

Sludge Ice.—Small pieces of brash ice saturated by the salt water.

Snout (of glacier).—The lower extremity of a glacier.

Snow Line.—The line representing the level above which snow, not exceptionally protected, remains unmelted throughout the year.

Stream.—A drifting line of loose ice.

Striæ.—Scratches made by bits of grit frozen in ice on rock surfaces, smoothed by ice.

Terminal Moraine.—Rock débris at the lower end of a glacier.

Till.—Some authors restrict the term *till* to material containing more or less angular material derived from the neighbouring valley system, applying *boulder clay* to that where the materials are derived from more various quarters and more often rounded—others use the terms as synonymous.

Tongue.—A mass of ice projecting under water from a floe or an iceberg, and generally distinguishable at a considerable depth in smooth water. It differs from a calf in being fixed to and forming part of the larger body.

Water Sky.—The dark appearance of the sky over open water, seen from a distance, in the ice.

Young Ice.—Nearly the same as bay ice; but applied to ice more recently formed.

THE ANTARCTIC MANUAL.

I.

ASTRONOMICAL DATA:

ECLIPSE OF THE SUN; OCCULTATIONS; AND PHOTOMETRIC OBSERVATIONS OF JUPITER'S SATELLITES.

(Communicated by the Superintendent of the 'Nautical Almanac.')

ECLIPSE OF THE SUN, SEPTEMBER 21, 1903.

In longitude 165° East and latitude 75° South this Eclipse commences September 21, at 3 h. 36·0 m. local mean time at 283° from the North point of the sun's disc towards the East and 116° from the vertex towards the East, and ends at 5 h. 33·7 m. at 114° from the North point towards the East and 309° from the vertex towards the East. The magnitude of the Eclipse at the greatest phase is 0·903.

For any position not far from the above, the East longitude of which is λ and geocentric latitude l, the *Greenwich* time t of commencement of the Eclipse may be found from the following formulæ (South latitude to be taken as negative):—

$$\text{Cos}\,\omega = -1\cdot66173 - [0\cdot24229]\sin l + [9\cdot78343]\cos l\cos(\lambda - 20°\,4'\cdot4)$$

$$t = 16\text{h.}\,37\text{m.}\,51\text{s.} - [3\cdot56147]\sin\omega - [3\cdot34482]\sin l - [3\cdot80377]\cos l\cos(\lambda - 18°\,57'\cdot0)$$

Contact on sun's limb, $-\omega + 19°\,10'\cdot0$ from the North point towards the East, and the *Greenwich* time t of ending from

$$\text{Cos}\,\omega = -1\cdot65131 - [0\cdot24428]\sin l + [9\cdot76048]\cos l\cos(\lambda + 9°\,27'\cdot1)$$

$$t = 16\text{h.}\,38\text{m.}\,8\text{s.} + [3\cdot53870]\sin\omega - [3\cdot29917]\sin l - [3\cdot78298]\cos l\cos(\lambda + 9°\,22'\cdot1)$$

Contact on sun's limb, $\omega + 18^\circ\ 10'\cdot 3$ from the North point towards the East; and applying the longitude expressed in time to t the local mean times of the commencement and ending of the Eclipse are obtained. The quantities within square brackets are logarithms, and those in the second equations, logarithms of seconds of time. The correction to be applied to the geographical to obtain the geocentric latitude (l) is, for

°	″
70 . .	− 7·5
71 . .	− 7·2
72 . .	− 6·9
73 . .	− 6·6
74 . .	− 6·2
75 . .	− 5·9
76 . .	− 5·5
77 . .	− 5·1
78 . .	− 4·8
79 . .	− 4·4

The correction is to be subtracted (numerically) from the geographical latitude.

OCCULTATIONS.

The list appended includes those stars of the 'Nautical Almanac' Catalogue, to magnitude 5·5 inclusive, the occultation of which may possibly be visible in 75° South latitude and 165° East longitude. In order to ascertain with certainty whether any star is occulted, and the circumstances of the occultation, the formulæ given on pages 626–628 of the 'Nautical Almanac, 1902,' should be employed. A copy of a table to be used with the formulæ is given. An example, illustrating the use of the formulæ for an actual case, is appended.

Occultations of Stars to the 5·5 Magnitude inclusive that may be visible in or near 75° S. Lat. and 165° E. Long.

Date.	Star's Name.	Mag.	Local Mean Time of ☌ in R.A. of ☾ and ✱ h.	m.	s.
1902					
Feb. 26	*h* Virginis	5·5	11	33	2
27	λ Virginis	4·6	10	33	12
Mar. 21	π Leonis	5·0	11	4	1
25	*h* Virginis	5·5	19	46	3
28	ζ⁴ Libræ	5·4	6	50	13
Apr 1	ν Sagittarii	4·7	20	27	58
2	B.A.C. 6746	5·5	6	52	32
4	ξ Aquarii	4·8	13	20	44
22	*h* Virginis	5·5	2	49	59
29	ν Sagittarii	4·7	4	2	51
29	B.A.C. 6746	5·5	14	36	42
May 1	ξ Aquarii	4·8	22	14	18
4	κ Piscium	5·0	2	15	10
19	*h* Virginis	5·5	8	48	47
21	ζ⁴ Libræ	5·4	20	23	1
26	ν Sagittarii	4·7	10	26	26
26	B.A.C. 6746	5·5	21	3	26
June 11	π Leonis	5·0	5	36	38
23	B.A.C. 6746	5·5	2	50	29
27	κ Piscium	5·0	17	20	51
July 8	ο Leonis	3·8	6	9	9
10	75 Leonis	5·4	2	12	3
10	79 Leonis	5·5	5	25	55
14	μ Libræ	5·4	11	7	32
15	θ Libræ	4·3	18	46	37
20	B.A.C. 6746	5·5	8	55	37
26	δ Piscium	4·6	13	53	7
Aug. 6	*d* Leonis	5·0	3	43	27
10	μ Libræ	5·4	18	23	15
12	θ Libræ	4·3	1	50	8
13	24 Scorpii	5·2	0	54	9
16	ν Sagittarii	4·7	5	32	22
16	B.A.C. 6746	5·5	16	0	25
21	λ Piscium	4·7	11	45	30
22	δ Piscium	4·6	19	12	57
Sept. 7	μ Libræ	5·4	2	35	55
8	θ Libræ	4·3	9	44	0
9	24 Scorpii	5·2	8	41	39
12	ν Sagittarii	4·7	13	35	12
Oct. 5	θ Libræ	4·3	17	57	25
6	24 Scorpii	5·2	16	47	10
16	δ Piscium	4·6	11	0	43
27	79 Leonis	5·5	15	9	56
1903					
Feb. 16	*m* Virginis	5·3	12	48	11
23	υ Sagittarii	4·7	7	42	21
Mar. 11	ξ Leonis	5·2	7	24	1
18	η Libræ	5·5	7	34	17
19	φ Ophiuchi	4·4	5	40	35
22	υ Sagittarii	4·7	15	27	5
26	κ Aquarii	5·4	17	17	28
Apr. 12	*m* Virginis	5·3	7	54	12
14	γ Libræ	4·1	12	36	41
14	η Libræ	5·5	16	33	53
15	φ Ophiuchi	4·4	14	24	55
19	B.A.C. 6746	5·5	10	17	14
23	κ Aquarii	5·4	2	1	29
May 9	*m* Virginis	5·3	15	27	57
12	η Libræ	5·5	0	40	26
12	φ Ophiuchi	4·4	22	32	10
16	υ Sagittarii	4·7	7	21	22
16	B.A.C. 6746	5·5	18	3	39
June 1	ξ Leonis	5·2	1	51	25
8	γ Libræ	4·1	3	18	52
8	η Libræ	5·5	7	19	38
9	φ Ophiuchi	4·4	5	23	58
12	υ Sagittarii	4·7	14	21	4
13	B.A.C. 6746	5·5	1	2	10
July 5	γ Libræ	4·1	8	54	59
6	φ Ophiuchi	4·4	11	14	3
10	B.A.C. 6746	5·5	7	16	14
26	48 Leonis	5·2	21	23	35
30	κ Virginis	4·3	23	47	58
Aug. 1	γ Libræ	4·1	14	42	25
2	φ Ophiuchi	4·4	16	58	28
6	υ Sagittarii	4·7	2	34	47
6	B.A.C. 6746	5·5	13	16	21
8	ν Aquarii	4·5	8	20	58
13	ζ' Piscium	5·4	13	38	22
26	θ Virginis	4·4	3	18	20
27	κ Virginis	4·3	7	49	20
28	γ Libræ	4·1	21	49	41
Sept. 2	υ Sagittarii	4·7	8	59	25
2	B.A.C. 6746	5·5	19	41	37
4	ν Aquarii	4·5	14	45	32
5	*c'* Capricorni	5·2	8	49	39
23	κ Virginis	4·3	17	25	36
26	φ Ophiuchi	4·4	7	53	2
29	υ Sagittarii	4·7	16	16	1
Oct. 2	*c'* Capricorni	5·2	16	7	56
22	γ Libræ	4·1	16	6	4
27	B.A.C. 6746	5·5	10	57	18

Note. The hours of Mean Time are counted from Mean Noon of each day.

TABLE FOR REDUCING THE *TRUE* TO THE *APPT.* ☌ IN R.A.

Hour Angle h at true ☌				C	$C^{(1)}$	Hour Angle h at true ☌				C	$C^{(1)}$
				+ −	Same sign as h					+ −	Same sign as h
h.	m.	h.	m.			h.	m.	h.	m.		
0	0	12	0	25	0	3	0	9	0	18	71
	10	11	50	25	4		10	8	50	17	74
	20		40	25	9		20		40	16	77
	30		30	25	13		30		30	15	79
	40		20	25	17		40		20	14	82
	50		10	25	22		50		10	14	84
1	0	11	0	24	26	4	0	8	0	13	87
	10	10	50	24	30		10	7	50	12	89
	20		40	24	34		20		40	11	91
	30		30	23	38		30		30	10	92
	40		20	23	42		40		20	9	94
	50		10	22	46		50		10	8	95
2	0	10	0	22	50	5	0	7	0	7	97
	10	9	50	21	54		10	6	50	5	98
	20		40	21	57		20		40	4	98
	30		30	20	61		30		30	3	99
	40		20	19	64		40		20	2	100
	50		10	19	68		50		10	1	100
3	0	9	0	18	71	6	0	6	0	0	100

Then T, denoting the approximate mean time of appt. ☌, in units of an hour,

$$T = \text{mean time true ☌} + \frac{C^{(1)}}{a_1 f - C}$$

in which a_1 must be used in minutes of arc; also $f = \frac{[0\cdot2310]}{\cos l}$, the value of which for latitude

°		
70	. .	$= 4\cdot98$
71	. .	$= 5\cdot23$
72	. .	$= 5\cdot51$
73	. .	$= 5\cdot82$
74	. .	$= 6\cdot18$
75	. .	$= 6\cdot58$
76	. .	$= 7\cdot04$
77	. .	$= 7\cdot57$
78	. .	$= 8\cdot19$
79	. .	$= 8\cdot92$

μ Libræ on July 14, 1902.

	h.	m.	s.	
$T_0 =$	0	7	32	(time of Conjunction).
	+	27	29	corr. from Table on preceding page.
$T =$	0	35	1	

$\left\{ \begin{array}{l} q_0 = -1\cdot1280 \; p' = \cdot5360 \; q' = -\cdot1187 \\ p = +\cdot2455 \; q = -1\cdot1824 \end{array} \right\}$ N. A., 1902, page 516.

$\left\{ \begin{array}{l} d = 11^h \text{ E} \quad \phi - 75^\circ \\ A = 14^h\, 44^m\, 0^s \quad D - 13^\circ 44'\cdot6 \end{array} \right\}$ from N. A., 1902, pp. 496 and 516.

Log X	9·99842 (N. A., p. 593)			
Log sin ϕ	− 9·98494			
Log ρ sin ϕ'	− 9·98366			
	h.	m.	s.	
T + d	11	35	1	
Correspondg. sidl. time = μ	19	0	47	
A	14	44	0	
μ − A	4	16	47	
μ − A (in arc)	64° 11′·8			
Log sin (μ − A)	+ 9·95439			
Log ρ cos ϕ'	9·41438			
Log u	+ 9·36877			
u	+ 0·2338			
p	+ 0·2455			
$p - u$	+ 0·0117			
Log ρ cos ϕ' cos (μ − A)	+ 9·05315			
Log μ'	9·41916			
Log u'	+ 8·47231			
u'	+ 0·0297			
p'	+ 0·5360			
$p' - u'$	+ 0·5063			
Log m sin M	+ 8·06819			
Log m cos M	− 9·43854			
Log tan M	− 8·62965			
M	177° 33′·6			
Log cos M	− 9·99960			
Log m	9·43894			
Log n	9·71340			
Log k	9·43542			
Log cos (M − n)	+ 9·38544			
Log $-\frac{m}{n}$	− 9·72554			
Log τ	− 9·11098			
τ	− 0^h ·129			

Log Y	0·00138 (N. A., p. 593)
Log cos ϕ	9·41300
Log ρ cos ϕ'	9·41438
Log ρ sin ϕ'	− 9·98336
Log cos D	9·98738
Sum	− 9·97074 (1)
Log ρ cos ϕ'	9·41438
Log sin D	− 9·37580
Log cos (μ − A)	+ 9·63877
Sum	− 8·42895 (2)
Nat. No. (1)	− 0·9348
− Nat. No. (2)	+ 0·0269
v	− 0·9079
q	− 1·1824
$q - v$	− 0·2745
Log ρ cos ϕ' sin D	− 8·79018
Log sin (μ − A)	+ 9·95439
Log μ'	9·41916
Log v'	− 8·16373
v'	− 0·0146
q'	− 0·1187
$q' - v'$	− 0·1041
Log n sin N	+ 9·70441
Log n cos N	− 9·01745
Log tan N	− 0·68696
N	101° 37′·1
Log sin N	9·99101
M − N	75° 56′·5
Log sin (M − N)	+ 9·98680
Log $\frac{m}{k}$	0·00352
Log cos ψ	+ 9·99032
ψ	12° 3′·0
Log sin ψ	+ 9·31966
Log $\frac{k}{n}$	9·72202
Sum	9·04168
Nat. No.	0^h ·110

Correction at Immersion − 0·239 h. = − 14·3 m.
Emersion − 0·019 h. = − 1·1 m.

Local Mean Time of Immersion = 11 h. 35·1 m. − 14·3 m. = 11 h. 20·8 m.
Emersion = 11 h. 35·1 m. − 1·1 m. = 11 h. 34·0 m.

$Q_1 = 102^\circ - 90^\circ + 12^\circ = 24^\circ$ $\qquad Q_2 = 102^\circ - 90^\circ - 12^\circ = 0^\circ$

(Angles from N point at immersion and emersion respectively.)

$V_1 = 24^\circ - 166^\circ = 218^\circ$ $\qquad V_2 = 0^\circ - 166^\circ = 194^\circ$

(Angles from Vertex at immersion and emersion respectively.)

See also N. A., 1902, pages 628, 629.

PHOTOMETRIC OBSERVATIONS OF THE ECLIPSES OF JUPITER'S SATELLITES.

It is suggested that observations of the eclipses of Jupiter's satellites should be included in the programme of work to be undertaken for the determination of longitudes. The mode of observation which can be most readily utilised for such a purpose appears to be that in which the reading of a wedge photometer is recorded, corresponding to the extinction of a satellite at different times during the progress of its eclipse. Professor Sampson, of Durham, who is engaged in the discussion of the photometric observations of these eclipses made at the Harvard College Observatory, strongly recommends this course, and has been so kind as to furnish suggestions as to the method of observation to be followed, which his familiarity with the subject renders of great value.

The following will be the method of observing a disappearance: before the brightness begins to diminish make 6–10 measures of it, noting also the time; when it begins to fall off, set the photometer so that the satellite is just seen, read the photometer, wait and note the time of disappearance; set the photometer again so that the satellite is just seen, and repeat. This is to be done as often and as rapidly as allows of steady work. But uniformity rather than great numbers of observations gives the light curve clearly.

Mutatis mutandis. The same will apply to the observation of a reappearance.

In recording the observations all that is required is the chronometer time at each extinction, and the corresponding reading of the photometer. In the subsequent reductions the former must, of course, be corrected for adopted error on local time, and the latter for error of scale reading. It will be well to secure observation of the eclipses of all four of the bright satellites; obtaining, when possible, observation of the disappearances and the corresponding reappearances of III. and IV.

It is most important that the observation should in each case include a number of readings corresponding to the extinction of the *fully illuminated* satellite. There is appended, as a specimen, a copy of the record of an eclipse of each of the satellites, as recorded at the Harvard College Observatory.

SPECIMENS OF HARVARD ECLIPSES.

O–C	Mag.	O–C	Mag.	O–C	Mag.	O–C	Mag.
1884/4/28. III. R.		+104	+0·6	+102	+0·4	+10	+2·1
		112	0·7	108	0·4	17	2·0
+102*	+2·2	120	0·4	112	0·3	24	1·9
112	2·3	126	0·3	118	0·2	31	1·8
120	2·3	133	0·3	123	0·3	36	1·5
128	2·4	140	0·6	129	0·2	42	1·7
136	2·0	148	0·5	136	0·3	49	1·9
148	1·9	155	0·5	142	0·4	56	1·9
160	2·1	164	0·4	148	0·3	63	1·8
172	1·5	174	0·1	153	0.1	70	1·5
183	0·8	182	0·0	158	+0·1	76	1·7
191	0·7	190	+0·1	162	0·0	84	1·9
202	1·1	200	0·2	168	−0·2	*104	1·5
213	1·1	210	+0·2	177	−0·1	*125	1·6
222	0·6	*242	0·0	184	+0·1	*148	1·4
233	0·6	*280	−0·1	190	0·0	*178	1·0
245	0·7	*357	+0·1	*211	−0·1	*210	1·0
257	0·7	*403	+0·1	*239	+0·1	*235	0·7
270	0·7	*436	0·0	*265	−0·1	*263	0·6
*308	0·7	*475	0·0	*295	+0·1	*293	0·8
*360	0·7	*511	0·0	*331	−0·1	*320	0·6
*414	0·1	*549	0·0	*382	+0·2	*345	0·7
*461	0·2	*593	−0·1	*410	−0·1	*373	0·5
*525	0·3	*631	−0·1	*437	0·0	*421	0·4
*585	0·4					*457	0·5
*684	+0·3	1884/5/9. II. R.		1884/5/10. IV. R.		*490	0·4
*735	−0·1					*519	0·2
*784	+0·6					*547	0·4
*846	−0·1	+9	suspected	−116	suspected	*577	0.2
*896	0·0	14	seen	108	seen	*613	0·0
*749	0·0	21	+2·7	94	+3·3	*641	0·0
*+1021	−0·2	28	2·4	87	3·1	*675	0·2
		35	2·0	78	2·5	*711	0·2
		40	1·8	70	2·5	*749	0·2
1884/5/1. I. R.		44	1·6	62	2·9	*803	0·0
		49	1·5	56	3·0	*841	0·2
+31	+2·0	54	1·5	48	2·3	*877	0·2
42	1·5	59	1·3	40	2·2	*917	+0·1
50	1·4	64	1·5	34	2·3	*956	−0·1
57	1·2	69	1·5	27	2·2	*1001	−0·1
64	0·9	74	1·3	21	2·2	*1041	−0·1
70	0·8	80	1·1	14	2·2	*+1080	0·0
80	0·8	86	0·8	−6	2·1		
90	1·1	92	0·5	0	2·2		
+97	+0·8	+96	+0·5	+5	+2·1		

O–C = observed time of recorded magnitude—N. A. time of disapp. (or reapp.) in seconds.

* Indicates the more deliberate observations.

II.

TIDAL OBSERVATIONS.

By G. H. Darwin, F.R.S.

The dynamical theory of the tides on an ocean lying on a rotating planet presents a problem of such difficulty that mathematicians have hitherto only succeeded in obtaining a solution where the ocean covers the whole planet, or where it is bounded by coasts which follow parallels of latitude round the whole circumference of the planet. Moreover, success has only been attained where the depth of the ocean is constant as we travel along a given parallel, although it has been found possible to conceive the depth as varying with the latitude according to some simple law. The conditions thus postulated by the mathematicians are clearly very different from those which obtain on the earth, and it might seem at first sight as if science could merely record a failure in the presence of the tidal problem. This is, however, very far from being the case, for by methods depending in part on theory and in part on observation, it has been found possible to make accurate tidal predictions and to learn much about the tidal oscillations of our complex system of oceans. But this is not the place in which to pursue further this branch of our subject, and we have only drawn attention to these considerations because they indicate the peculiar importance of tidal observation in the Antarctic Ocean from a scientific point of view. This region is the only one on the earth in which those conditions are even approximately fulfilled in which a complete dynamical solution has been attained, because here only do we find an ocean uninterrupted throughout the whole circumference of the planet. It is true that the existence of the Pacific and Atlantic Oceans must introduce conditions which differ widely from those postulated by the theory, but it must clearly be important to obtain observations in an ocean which conforms, although roughly, to the theoretical standard, especially when we know that observations in this region are almost entirely wanting.

In harbours frequented by shipping, trustworthy tide-tables have a considerable commercial value, but in the case in point this element is, of course, entirely wanting, and the minuter details of the phenomena at the place of observation present but little interest; what we wish to know, is the nature of the tidal oscillation affecting the whole ocean.

The construction of accurate tidal predictions demands a continuous series of observations extending over several years. Such extensive data are needed, not on account of the complexity of the tidal oscillations themselves, although they are pretty complicated, but because it is only possible to eliminate the incessant meteorological perturbation of the tide by considering the average as estimated over a long period of time. In the case of the Antarctic Ocean these prolonged observations are neither practicable nor desirable. It must not, however, be concluded that very rough observations will suffice, for accuracy is needed for the determination of the main outline of the phenomena, and duration of observation is a necessary condition for even the approximate elimination of the varying effects of wind and barometric pressure. It should also be noted that observation extended over two months will give considerably more than twice the accuracy attainable by the results for one month.

Tidal observations are necessarily conducted from the shore, and the existence of land exercises a perturbing influence on the oceanic tide which it is our object to examine. Hence, on this account alone, it would be highly desirable that the observations should not be confined to a single station. But, further, since the tides depend on latitude, it would be of especial value that observations should be made at such a place as Kerguelen Island, and also on the Antarctic Continent itself. The tides on the continent are more likely to suffer perturbation from the existence of land, than those at so isolated a station as Kerguelen Island. Hence it is eminently to be desired that the observations in the extreme south should be taken in two or more places.

The multiplication of stations and the prolongation of the period of observation present conditions which are obviously incompatible, and their rival claims can only be decided as a compromise. It may, I think, be stated that the shortest period during which observations should be made is a fortnight, but that a month is a much more desirable period. The naval requirements of the Expedition will probably give the observers but little choice as to the number of stations and the periods of observation. I would then merely advise

that observations should be made at several places, and that, whilst a fortnight should be looked on as a minimum, yet even the results for a week would not be without value.

Tidal observations with a tide-gauge are not appropriate for an expedition such as that now in preparation, and reliance must be placed on observations by eye. The ingenuity of naval officers is never wanting in the construction of an apparatus for observations of this kind. Until recently it has been the practice in the navy to observe the times and heights of water at high and low tide, and the times have often been tabulated in apparent instead of in mean time. But experience has now shown that it is far more convenient for the determination of the law of the tide that the observations should be taken at equidistant intervals of the mean time of the place. In their work at Campbell Island the French Expedition took observations every half-hour of the day and night. But, in my opinion, all the needed accuracy may be attained by means of hourly observations. If it is deemed desirable, observations of high and low water might also be made, but I am not inclined to consider this as necessary. Dr. Haughton, in his 'Arctic Manual,' speaks of observations every four hours during the night as perhaps sufficient, but I find it hard to coincide with this opinion. If the exigencies of the service render hourly observations impossible, we may have to put up with two-hourly observations. In the subsequent numerical treatment, the first step would be the interpolation of the missing hourly values, and thus the strength of the results would be much weakened by the intermission of several hours.

At each tidal station meteorological observations will, no doubt, be made, and thus the materials will be at hand for the empirical correction of the observed heights, if such correction should be found possible.

It has been observed that the rise and fall of the tide is apt to occur by a series of impulses, so that the trace drawn by a tide-gauge is usually more or less notched. The degree of irregularity is found to vary much according to the weather, and according to the site of observation. In estuaries and land-locked bays the zigzag is often very pronounced, but even in such sites the degree of perturbation varies much with the exact position of the tide-gauge. It is highly desirable that a position should be chosen where the irregularity is not pronounced, but it is not always easy to decide on the most favourable spot by mere inspection. During the last thirty years much attention has been paid to these secondary undulations, and they have been shown to be local vibrations of the partially enclosed

sheet of water analogous to the seiches by which the Swiss and other lakes are perturbed.

These oscillations merely confuse the tidal phenomena, and it is desirable to eliminate them as far as possible. In order that it may be known to what extent they disturb the results at the chosen point of observation, it will be well that the series should begin with observations taken every four or five minutes during an hour or two, repeated at intervals twice or thrice during the first day or two. Since seiches always exist to some extent, each of the subsequent hourly observations should be the mean of several readings taken just before and just after the exact hour. It may be suggested that it would suffice to take the mean of five readings taken at intervals of two and a half minutes, from five minutes before the hour to five minutes after it. If, however, the preliminary examination suggested above should show that the seiches are apt to be considerable in amplitude, and to have a long period—such as a quarter of an hour to twenty minutes—it might be well to extend the period further before and after the hour.

February 18, 1901.

III.

PENDULUM OBSERVATIONS.

By R. T. Glazebrook, F.R.S.

The apparatus is arranged in order to measure accurately the times of vibration of three pendulums. The period of each pendulum is about half a second, and these periods are determined by comparison with a clock or chronometer.

The main observing station will be adjacent to the winter quarters, and here the clock can be used. If opportunity occurs for making observations when at a distance from the base, the chronometer is available.

Observations at the Base.—Since the mean rate of a clock over 24 hours may often be appreciably different from its rate for a short interval between the times for which the mean rate is determined, it is desirable that, wherever possible, (1) the pendulum observations should extend over the 24 hours; and (2) that astronomical observations to determine the rate of the clock should be made at the beginning and end of that period.

To secure (1) each pendulum should be swung for 8 hours, while to secure (2) the observations should be begun at a time at which star transits for the determination of the time are possible.

A complete set of observations will occupy more than the 24 hours, but much valuable information can be obtained without taking a complete set on every occasion. Moreover, it must be noted that observations are not continuous during the 24 hours. When the apparatus is properly adjusted readings at intervals of 8 hours suffice, though at first a somewhat shorter time than this should be allowed to elapse between the observations.

The method of coincidences is used to determine the periods.

Light from a lamp is reflected through a narrow horizontal slit towards the pendulum-stand. A mirror attached to the upper part of the pendulum reflects the ray back, and it is viewed through a telescope which is adjusted so that when the pendulum is at rest the

image of the slit coincides with one of the cross wires. A shutter, worked by an electromagnet, moves across the slit. This shutter also carries a slit, and the adjustments are such that in one position the two slits are in the same horizontal line, and the light can pass through; in any other position of the shutter it is obscured. The electromagnet is actuated by means of a current which passes through the clock, and is broken once a second. Thus, the shutter oscillates once a second, in time with the clock, and once a second an instantaneous beam of light is emitted from the slit and reflected by the pendulum, appearing as a flash coincident with the cross wire.

When the pendulum is moving the apparent position of the flash will depend on the position of the pendulum when the reflection occurs. If the pendulum is vibrating exactly in half-seconds it will have completed exactly two vibrations in the interval (one second) between two flashes, and the flash will always occupy the same position on the field. If the period of the pendulum is slightly less or slightly greater than half a second the position of the flash will shift on the field. If it be watched, it will be found to move gradually to one side of the cross wire and then to come back, until after a certain number of seconds it again coincides with the cross wire; it then continues to move to the opposite side of the wire, and after another interval reverses its direction and crosses the wire again, now moving as at first. In taking the observations it is necessary to observe transits both from right to left and from left to right.

The time which it is required to measure accurately is the interval between two consecutive transits of the cross wire in the same direction. This we shall call the coincidence interval. Now we know that at the beginning and end of the coincidence interval the pendulum was in exactly the same position. During the interval, then, it has completed a whole number of swings. If it had been a half-second pendulum exactly, this number would have been twice the number of seconds in the interval. If the period is slightly greater than half a second the pendulum falls behind the clock at each swing, and at the end of the coincidence period it has fallen behind by exactly one swing. Thus, if the coincidence interval be s seconds, we arrive at the result that in s seconds the pendulum has executed $2s - 1$ swings.

Thus, the complete period of the pendulum is $\frac{s}{2s-1}$ seconds.

If the period of the pendulum be less than half a second it will, during the coincidence period, gain on the clock, and the complete period of the pendulum will be $\frac{s}{2s+1}$ seconds.

In the pendulums supplied to the Expedition the first formula

holds. Thus, in some preliminary observations with one of the pendulums of the Expedition a coincidence period of 28·750 secs. was observed. This gives a period of 0·50884 sec. To this period, however, so determined, various corrections are required, and the apparatus is arranged to enable these to be obtained with ease.

Temperature Correction.—The dimensions of the pendulum vary with the temperature. The observed time of swing, therefore, must be corrected to some standard temperature for each degree of temperature. The amount of this correction will be determined at the National Physical Laboratory before the Expedition starts. In order to determine the temperature accurately a fourth dummy pendulum is provided, which contains a thermometer embedded in the bulb. This thermometer can be read through a glass panel in the outer case while the pendulums are being swung, and frequent readings should be taken during the observations, the time of the readings being noted. From these readings the mean temperature during the observations is obtained, and it is this which is to be used in the correcting term.

It must be noted, however, that the range of temperature over which it is possible to determine this correction in England is very small compared with the range to which the pendulums will be exposed, and a determination of the correction during the Expedition will be of real value. If it should be found that the temperature of the observatory hut varies greatly during the 24 hours, it would be of service to keep a thermograph running during the observations. In any case the temperature of the air should be recorded from time to time.

If we call k the change in period for 1° of temperature, T the standard temperature, and t the mean temperature during an observation, then the correction to the observed time of survey from this cause is $-k(t - \mathrm{T})$.

Pressure Correction.—The period depends, to some extent, on the pressure of the air in which the pendulum swings. The simplest way of avoiding trouble from this cause is to keep the pressure constant during an observation. Moreover, the swing is damped by the presence of the air, and as it is desirable that the swings should continue for a long time, the air pressure should be reduced.

To secure these ends the swinging pendulums are enclosed in an air-tight case with glass windows, through which the observations are made. A gauge is fitted to this case, by means of which the pressure inside can be read, and an air-pump is supplied to reduce the pressure to some definite value.

In the U.S. survey a pressure of 60 mm. at 0° C. was adopted as

the standard. This may prove to be rather low in the present case, but we will assume that it is the pressure aimed at.

It is impossible, however, always to secure this pressure exactly, and thus a correction is required to reduce readings to the standard pressure. For this purpose the pressure p and the temperature t are observed. To reduce the pressure p to what it would be at 0° we divide it by $1 + \cdot 00367\, t$, and obtain as the difference from the standard the value of $60 - \frac{p}{1 + \cdot 00367\, t}$.

Now observations show that for a small range of pressure the correction to the period is proportional to the change of pressure: if we call k' the increase of period produced by a pressure-change of 1 mm. the correction due to a change of $60 - \frac{p}{1 + \cdot 00367\, t}$ will be $k' \left\{ 60 - \frac{p}{1 + \cdot 00367\, t} \right\}$. The quantity k' will be determined by observations before the start.

It must be remembered that while accuracy is secured by working at a low pressure this is not absolutely essential to success, though the time over which the observations can be extended will be seriously reduced if the pressure be high. At the same time should it be impossible for any reason to maintain the low pressure, experiments made under a greater pressure would, if carefully conducted, give important information. In all cases the pressure at the time of the observation must be carefully recorded.

Arc Correction.—The period depends on the amplitude of the surveys of the pendulum. The correction on this account is given if the amplitude of the first and last surveys can be found.

To obtain these a vertical scale is attached to the front of the box which contains the shutter. By shifting the lamp used with the flash apparatus this scale can be illuminated, and its reflection on the pendulum mirror made visible. By reading the divisions of the scale which coincide with the cross wire at the extremities of the swing, the amplitude is given, if we know the distance between the scale and the mirror. In calculating the amplitude it must be remembered that the reflected ray is turned through twice the angle through which the mirror moves.

In the instrument supplied the small divisions are about 3 mm. in length, and at a distance of 2 metres the angle subtended by a division is very nearly 5′. If the amplitude of the oscillation be one division the angular amplitude of the swing of the pendulum will be 2′·5.

The correction to the period which arises from this is given by the formula

$$\text{Correction} = -\frac{\text{P M}}{32}\,\frac{\sin(\phi + \phi')\sin(\phi - \phi')}{\log\sin\phi - \log\sin\phi'}$$

when ϕ and ϕ' are the observed amplitudes, P the period and M the modulus of common logarithms, 0·4343.

Rate Correction.—This is necessary in order to correct for the rate of the clock. The correction is

$$+\,0\cdot00001157\ \text{R P}$$

where R is the observed rate in sidereal time in seconds per day, P the period. R is positive if the clock is losing.

Flexure Correction.—The stand is not perfectly rigid, and in consequence of its yielding a correction is necessary to the observed period. In the instrument two of the pendulums B, C, are mounted so that they swing in the same plane on opposite sides of the support; the plane of vibration of the third pendulum is at right angles to that of B and C.

If the stand were perfectly rigid and B were set in motion, A and C being at rest, the motion of B would not be transmitted to C and it would remain at rest. In consequence of the want of rigidity C is set in motion, and since the period of C is nearly the same as that of B a slight yielding of the stand will produce a considerable motion in C. From observations on the motion of C the correction to the period of B can be determined.

To determine this correction pendulum B is set swinging, pendulum C being at rest; after a short time it will be found that C is in motion. Observations are made of its amplitude at equal intervals of time—the length of the interval will depend on the amount of yielding—and it will be found that the amplitude of C gradually increases while that of B decreases. After a time the amplitude of C reaches a maximum, it then decreases again, passing through a minimum and so on in a regular cycle.

A series of observations are made of the time and the corresponding arcs of vibration a, a' of the two pendulums B and C respectively, then if s, s' be the period of the two, it can be shown that the flexural correction to s is given by the expression

$$\sigma = \frac{a}{a'}\,\frac{(s' - s)}{2}\,\operatorname{cosec}\frac{\pi(s' - s)\,t}{2\,s\,s'}.$$

Correction for Damping.—Unless the air can be reduced to a low

pressure the swings of the pendulum rapidly damp down, and a correction is required in consequence.

If λ be the logarithmic decrement, T the observed time, T_0 the true time of swing, then it can be shown that

$$T_0 = T \frac{\pi}{\sqrt{\pi^2 + \lambda^2}}.$$

To find λ we observe the amplitudes of a number of successive swings. If C_1 be the amplitude of the first swing, C_n of the n^{th}, then λ is given by the equation

$$\lambda = \frac{1}{n-1} \log_\epsilon \frac{C_n}{C_1}.$$

If the pressure can be reduced to 50 or 60 mm. this correction will be very small indeed.

The observations will normally be conducted on land. If opportunity offered to take a set of observations on a fixed ice floe the experiment might be usefully made; in this case it would be desirable to know the thickness of the ice and the depth of the water. The object of the investigation is to determine the value of g, the acceleration due to gravity. For this purpose it is important to know, in addition to the time of swing, the latitude of the observing station and its height above sea level; the nature of the ground near the station should also be noted for the purpose of obtaining a value for the density of the material of the earth in the neighbourhood.

A situation should if possible be selected for the pendulum house, not in the immediate neighbourhood of any high ground; with a view of eliminating local inequalities some subsidiary observations at points in the neighbourhood of the central station may, if opportunity offers, be made.

If it is possible to transport the instrument to a point at a considerable distance to the south of the central station, so as to obtain a value for g at two positions differing appreciably in latitude, the information would be of value. In this case the geographical position and height above sea level of the second station should be determined.

As a specimen, a series of observations at Washington, taken from Appendix I. of the 'Report of the United States Coast and Geodetic Survey Department for 1894,' is given.

Pendulum Observations and Reductions.

Washington, D.C. (Coast and Geodetic Survey), 1894.

Swing No.	Pendulum.	Position.	Date. 1894.	Coincidence Interval.		Total Arc.		Temperature.	Pressure.	Period uncorrected.		Corrections (seventh decimal place).						Period corrected.		
				1824.	1823.	Initial.	Final.			1824.	1823.	Arc.	Tempe-rature.	Pres-sure	Rate 1824.	Rate 1823.	Flex-ure.	1824.	1823.	Mean.
				s.	s.	′	′	°C.	mm.									s.	s.	s.
1	A_4	R.	May 10	301·27	292·98	52	19	19·44	61	·5008312	·5008547	− 8	− 186	− 1	+ 290	+ 57	− 6	·5008401	·5008403	·5008402
2	A_4	D.	11	301·21	292·93	53	21	19·42	61	8314	8549	− 8	− 185	− 1	+ 290	+ 57	− 6	8404	8406	8405
3	A_5	R.	11	381·24	368·25	56	21	19·42	58	·5006566	·5006798	− 9	− 185	+ 2	+ 290	+ 57	− 6	·5006658	·5006657	·5006658
4	A_5	D.	11	381·28	367·47	55	20	19·42	60	6565	6812	− 9	− 185	0	+ 304	+ 67	− 6	6669	6679	6674
5	A_6	R.	12	404·20	389·33	53	21	19·34	58	·5006193	·5006430	− 8	− 182	+ 2	+ 304	+ 67	− 6	·5006303	·5006303	·5006303
6	A_6	D.	12	403·85	389·44	55	21	19·37	56	6198	6428	− 9	− 183	+ 4	+ 304	+ 67	− 6	6308	6301	6304
																		·5007124	·5007126	·5007124

IV.

TERRESTRIAL MAGNETISM.

MAGNETICAL INSTRUCTIONS FOR THE ANTARCTIC EXPEDITION, 1901.

By Captain E. W. Creak, F.R.S. R.N.

Regarding the observation of the elements of Terrestrial Magnetism as one of the principal objects of the present Antarctic Expedition, every effort should be made to secure as complete a magnetic survey of the region south of the parallel of 40° S. as circumstances will permit.

Enough is known of the magnetic elements in that region to show that, except where observations have been made on land, as in South America and Tasmania, large changes in the Magnetic Declination or Variation have been going on since the time of Ross's magnetic survey of 1839–43, the principal foci of such change being far out at sea, whilst the dip and intensity of the changes, of which there is scant information, are probably also subject to great alterations in their distribution.

It should be borne in mind that Kew Observatory is the primary base station of the whole series of magnetic observations, with which it is specially desirable to connect by absolute measurements of the magnetic elements, land stations at the Cape of Good Hope and Melbourne, Lyttleton (New Zealand) and an Antarctic station in Victoria Land.

The constants for the various instruments enumerated below have been determined at Kew, and it is necessary that immediately on the return of the Expedition to England, a re-determination of the constants should be made there.

The principal base station of the survey in southern latitudes will be at Melbourne, where there is a fully equipped magnetic observatory.

It is of great importance that a secondary base station should be established in Victoria Land, where, besides the other instruments, the differential instruments or Variometers can be successfully established.

Considering the large areas of open sea which the *Discovery* will probably traverse, and the possibility that circumstances may even prevent the landing of a party on the coast of Victoria Land, observations of the magnetic elements at sea are of great importance. It is with this view of the value of such observations that the ship has been specially designed, and every cause of disturbance from iron eliminated within a radius of 30 feet from the centre of the ship's observatory.

It is further probable that large local magnetic disturbances will be found in Victoria Land, in which case there should be no difficulty in obtaining normal values on board the ship so prepared as well as on ice.

For Observations on Land, the instruments furnished comprise:

(*a*) Portable Unifilar Magnetometers for determining the absolute Horizontal Force and Declination at the base stations. Two.

(*b*) Barrow's Dip Circles (in duplicate) for determining the Absolute Dip or Inclination. These circles are provided with additional needles for determining the Total Force by Dr. Lloyd's method. *These additional needles are never to be reversed or disturbed.* Deflection bars are also provided for determining the constant depending upon the distribution of magnetism in the two needles for force.

(*c*) A self-recording apparatus or system of Variometers for registering the diurnal variation in the Declination, Horizontal Force, and Vertical Force. (Professor Eschenhagen's system.)

(*d*) A special azimuth compass with tripod for observing the Declination. It is probable that by using this compass in combination with Barrow's Circle and Lloyd's needles, the magnetic elements may be observed on Antarctic land or ice with greater ease and precision than with the Unifilar magnetometer in combination with the Dip Circle.

(*e*) Small azimuth compasses, with socket to mount on a tripod (in duplicate) for travelling or sledging parties to observe the magnetic declination.

(*f*) Small compasses (in duplicate) to give direction of travelling to sledging parties.

For Observations on Board Ship, the instruments comprise:

(*a*) L. C.* Dip Circle and Intensity Apparatus (in duplicate) for determining the Absolute Dip and Relative Intensity at sea or on land. This instrument is specially designed for use in either hemisphere, in regions between the 40th parallels and the geographical

* Lloyd-Creak.

poles, the weight on the needle being attached to the upper end of the needle as shown by the Dip.

(*b*) Fox Dip and Intensity apparatus, or Fox Circle (in duplicate), for use at sea between any two land stations at which the absolute values of the Dip and Intensity can be observed. It is also recommended for use in sledging parties.

(*c*) A special Standard Compass for observing the Declination or Variation at sea and for use in swinging to ascertain the constants of the disturbing iron in the ship. The two cards of this compass have periods of 23 and 15 seconds respectively; the latter being provided for use in regions of low horizontal force.

(*d*) A gimbal stand for mounting the L. C. and Fox Circles and Fox Compass,* to be fixed in the centre of the ship's observatory.

(*e*) Fox Compass. Horizontal vibration needle, and Vertical vibration needle in Dip circle, for ascertaining the disturbing forces of the ship's iron at the centre of the ship's observatory or "Fox position." Also at Standard Compass position.

Observations at Land Stations.

It is considered that the Instructions given in the 'Admiralty Manual of Scientific Enquiry' (1886), art. Terrestrial Magnetism, will suffice for the guidance to observers in the method of observation and calculation of the results obtained by the Unifilar Magnetometer, Barrow's Circle, L. C. Circle, and Fox Circle at Land stations.

Special instructions for the Eschenhagen Variometers will be supplied with the instrument.

It is important that the magnetic survey in Southern waters should be preceded by observations at a base station at the Cape of Good Hope. The Cape Town magnetic observatory being disturbed by electric tramways, Simon's Bay offers a satisfactory alternative for such a base station. Here the Absolute Horizontal Force, Dip and Declination should be observed with great accuracy and the Constant A for Lloyd's needles on the Barrow's and L. C. circles respectively determined. Complete base observations, including those for weight equivalents, should also be made with the Fox circles.

On arrival at Melbourne immediate arrangements should be made for making complete observations with every instrument to be used in the survey at the Government Magnetic Observatory. This is not to include the Variometers, which are only intended for the extreme southern base.

Especially should the Absolute Horizontal Force and Dip be

* Special compass to be called the Fox Compass.

observed by both the Unifilar Magnetometers and both Barrow's Dip Circles; firstly to connect Kew and Melbourne magnetically; secondly to obtain fresh values of Constant A for the Dip Circles with the weights used at Simon's Bay, and then with heavier weights suitable for measuring the largely increased forces predominant in the Southern regions after leaving Melbourne. (*See* Chart of Total Force supplied to the Expedition.) The value of the observations of Intensity in Antarctic regions with Lloyd's needles is dependent upon the accuracy with which these base observations are made.

Observations at the Antarctic Land Station.

As soon as the Antarctic land station is selected and circumstances permit, the Variometers should be mounted and brought into action and kept so during the sojourn of the landing party.

It is expedient that the absolute determinations for zeros and scales values should be made once a week during the first month of the installation of the Variometers.

Hourly observations of the three elements are required to be made on the following term days agreeably with international arrangement, Greenwich mean time being adopted throughout. Commencing with 1st February, 1902, on the 15th February, and then on the 1st and 15th of every succeeding month ending on 15th February, 1903. Also observations for every 20 seconds from 10 A.M. to 11 A.M. G.M.T. on each of the above term days. Forms are supplied for registering the observations.

The series of observations made at Melbourne should be repeated at this Antarctic station. Values of the Total Force with the Barrow's Circle are expected to yield more reliable results here than those by the Unifilar magnetometer, owing to the low horizontal force prevailing and the liability of the horizontal needle to frequent and large disturbances.

As complete a magnetic survey of the neighbourhood of this Southern base as possible should be made, and the magnetic elements observed by sledging parties with the Fox circles and small azimuth compasses.

Observations of the Absolute Horizontal Force, Absolute Dip, Total Force by Lloyd's needles, and Absolute Declination should be made here once a month. Quiet days are recommended for this work.

Observations on Board the Ship.

Observation shows that a large number of land stations are affected by local magnetic disturbance, and normal values are only

to be obtained by extended magnetic surveys of the surrounding country. It has also been shown that the lands hitherto visited South of 40° S. are subject to like disturbance. Extended land surveys being probably out of the question for this Expedition, the normal values which can be obtained on board the ship which will traverse large tracts of sea and clear of the land are of great value.

As observation alone will show how far the instruments on board the ship are free from disturbance by the ship's iron, it is considered necessary to provide methods of computing the corrections for all observations in case of such disturbance.

1. *Declination or Variation.*

To obtain the correction for the deviation (δ) of the compass from the magnetic meridian in all latitudes, we require to know the value of the coefficients A, B, C, D, E, at a number of widely distributed positions on the globe. These can be obtained whenever the ship is swung to ascertain simultaneously the deviations of the Standard and Fox compasses. (*See* 'Admiralty Manual for Deviations of Compass,' 7th ed., 1901, pp. 50–63.) A, D, E, do not change by change of magnetic latitude. C changes inversely as the horizontal force. The changes in B may be computed by the following formulæ, B having been observed in two widely different magnetic latitudes:—

$$\left.\begin{aligned} \frac{P}{\lambda} + \frac{c}{\lambda} H_1 \tan \theta_1 &= \sin B_1 \,.\, H_1 \\ \frac{P}{\lambda} + \frac{c}{\lambda} H_2 \tan \theta_2 &= \sin B_2 \,.\, H_2 \end{aligned}\right\} \quad . \quad . \quad . \quad (1)$$

in which P is due to hard iron, and varies inversely as the horizontal force; *c* due to vertical induction in vertical soft iron and changing as the tangent of the dip. θ_1 and θ_2 the undisturbed dip at the two stations. H_1 and H_2 the horizontal force at the two stations expressed in terms of the horizontal force at Greenwich = $1 \cdot 0$.

The coefficients being known, δ for any direction of the ship's head can be computed by the equation

$$\delta = A + B \sin \zeta' + C \cos \zeta' + D \sin 2\,\zeta' + E \cos 2\,\zeta'$$

ζ' denoting the azimuth of the ship's head by the disturbed compass. Forms are provided to facilitate this computation.

It should be noted that whenever the ship is completely swung, any disturbance from the ship's iron is eliminated and valuable determinations of the Variations obtained.

The values of λ, μ and g (*see* 'Adm. Man. Dev. Compass,' pp. 65–74)

by the method of vibrations should be obtained on all occasions of the ship being swung in harbour, observing the precaution when landing the vibration instruments of avoiding positions on land subject to local magnetic disturbance. Much value is attached to values of μ obtained in Antarctic regions when the vibrations are observed on *ice* instead of land for reducing the force observations made on board (*see* below under Total Force). Forms for computing λ, μ and g, are included in those for δ.

2. *Inclination or Dip.*

In order to correct the observed dip, we require to know the constants A′, s, d, and V, and the coefficient N, in addition to the coefficients B, C, D, obtained for the Fox position when swinging—

$$A' = \lambda\,(1 + \sin D)$$

$$s = \lambda \frac{g}{(1 + \sin D)}.$$

These are constant in all latitudes, but should be confirmed by observation on large changes of latitude. With the value of s already known, coefficient N may be computed from observations made at the Fox position by the formulæ—

$$s \cos \zeta + N = \{(1 - 2 \sin D) \sin \zeta - \sin C\} \operatorname{cosec} \zeta' \tan \theta' \quad (2)$$

$$s \cos \zeta + N = (\cos \zeta + \sin B) \sec \zeta' \tan \theta' \quad . \quad . \quad . \quad . \quad (3)$$

Values of d and V can be calculated by the following formulæ—

$$\left.\begin{aligned} \frac{V}{A' H_1} + d \tan \theta_1 = \Delta_1 = \tan \theta_1 - N_1 \\ \frac{V}{A' H_2} + d \tan \theta_2 = \Delta_2 = \tan \theta_2 - N_2 \end{aligned}\right\} \quad . \quad . \quad (4)$$

In the formulæ (2), (3), (4), θ' is the observed dip, H and θ have the same meaning as in (1), ζ is the magnetic azimuth of the ship's head.

Corrections for the deviation of the dip needle from the normal due to the direction of the ship's head, may be computed by the formulæ (5) or (6)—

$$\tan \theta' = \frac{s \cos \zeta + N}{(1 - 2 \sin D) \sin \zeta - \sin C} \sin \zeta' \quad . \quad (5)$$

$$\tan \theta' = \frac{s \cos \zeta + N}{\cos \zeta + \sin B} \cos \zeta' \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The difference between the values of θ' so obtained and N being the deviation.

Note.—When the direction of the ship's head is between N. 45° E. and S. 45° E., or between N. 45° W. and S. 45° W., formulas (2) and (5) should be employed. In the Northern and Southern semicircles, between N. 45° E. and N. 45° W., and between S. 45° E. and S. 45° W., formulas (3) and (6).

The several corrections having been calculated, the observed dip (θ') requires three corrections—

1. For Index error (for Fox circle only).
2. For direction of ship's head.
3. For the vertical force of the ship = Δ.

3. *Total Force.*

Tables of Corrections for deviations of the Total Force, due to the direction of the ship's head, may be computed by the formula—

$$R' = A' H (s \cos \zeta + N) \operatorname{cosec} \theta' \quad . \quad . \quad . \quad (7)$$

The differences between the several computed values of R′ for eight or more equidistant directions of the ship's head, and the mean of the whole = R°, will give the corrections.

With the values of Δ taken from the corrections for dip, and the value of θ already obtained from the corrected values of θ', the Total Force R can be calculated by the formula—

$$R = (R^{\circ} \sin \theta^{\circ} + \Delta H) \operatorname{cosec} \theta \quad . \quad . \quad . \quad (8)$$

The values of θ° can be taken from those of $N = \tan \theta^{\circ}$.

When observations of R′ can be observed with the ship's head on or near both East and West by the Fox compass, the mean R′ = R°. Then if the value of μ be observed about the same time from vibrations on East and West, and also on neighbouring ice, the Vertical Force Z can be obtained by the formula—

$$Z = \frac{R^{\circ} \sin \theta^{\circ}}{\mu} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

As the taking the vibrations on ice will occupy a very short time compared with the full observation for force, this method is recommended when time presses and the ship is in smooth water.

General Remarks.

In addition to the Land stations mentioned above, the following are selected regions for observations in the ship:—

(*a*) Between the Cape of Good Hope and Melbourne, on or near the parallel of 40° S.

(*b*) As far South as possible between the Longitude of 160° W. and 115° E.

(*c*) Especially in the region comprised between Latitudes 65° S. and 80° S., Longitude 160° E. to 160° W.

(*d*) Also between 45° S. and 60° S., and between the Longitudes 120° E. to 140° E.

(*e*) From Melbourne to Cape Horn, between the parallels of 50° S. and 60° S.

(1) It is necessary before leaving England that the ship should be swung for deviation of the compass at the Standard and Fox positions, the coefficients λ and μ, and the constants g, being determined at the same time.

It is recommended that these initial observations should be made with great care, the resulting data being of great importance in showing the actual amount of disturbance caused by the iron in the ship, and the prospect in that respect for the future. Spithead is suggested as an excellent place for carrying out these observations.

(2) It is not necessary to swing the ship for observing the deviations of the Dip and Total Force from the normal, but to compensate for the omission of that laborious operation on different occasions, the ship should be swung for deviation of the compasses on the eight principal points as often as it can be conveniently done. Each swinging should occupy about one hour. The Fox compass must be invariably compared with the Standard compass when swinging.

(3) When the Fox circle is employed at sea the method of observing the deflections by *grains*, as well as by *deflectors*, should be adopted when possible, as by this means changes in the moment of the deflectors can be detected.

(4) The declination or Variation should, when practicable, be observed twice in the day at sea, and when the sun's altitude is below 30°.

(5) The Dip and Force should be observed daily at sea. In the high Southern latitudes the observations should be repeated during the day, the hours between 9 and 11 A.M., and 5 P.M. and 7 P.M., being recommended. The ship should be carefully steered during these observations, any departure from the course being notified to the observer in the observatory by an assistant stationed at the Standard compass, in order that the Dip circle may be adjusted to the meridian if required.

(6) Charts of the Declination and of Total Force are supplied. They will probably be liable to large corrections as the Magnetic

Survey goes on, and must be considered as somewhat wide approximations to the truth. The chart of Total Force should, however, be useful in deciding the size of the weight to be applied to the force needles in the Barrow and L. C. circles.

(7) It is necessary to keep the area comprised within the radius of 30 feet from the Fox position, free from movable iron during magnetic observations.

(8) No mechanical correctors should be used at the Fox position.

If a large deviation should be observed at the Standard compass on the East or West points, it might be corrected by a fore and aft magnet. The exact date of its application and removal must be noted, the ship being swung on each occasion.

The steering compasses should be fully corrected by soft iron and magnets as required.

(9) The books of forms supplied for registering magnetic observations are intended for retention in the ship. The spare forms for making copies of all observations to be sent to England as opportunity offers.

(10) Although Simon's Bay, Melbourne, Lyttelton and the Antarctic land station have been alone mentioned, observations at any other port of call during the voyage are much wanted. Amongst others the Falkland Islands may be specially mentioned, being also within the zone of operations.

(11) It seems to be a subject worthy of enquiry whether the disturbances of the needle from the normal are of the same character on ice as on land.

PROGRAMME FOR INTERNATIONAL CO-OPERATION DURING THE ANTARCTIC EXPEDITION IN THE YEARS 1902 AND 1903.

1. The work of the International co-operation at the time of the Antarctic explorations will consist of simultaneous observation of the magnetic and meteorological conditions of the Earth.

A. Observations of Terrestrial Magnetism.

2. The *Object* of these is to make available to science a series of separate pictures, which shall represent in detail the change taking place in the magnetic condition of the Earth as a whole in a definite

interval of time. A knowledge of this change forms the only basis on which a closer investigation of the fundamental problems of terrestrial magnetism can be founded.

3. The *Observing Stations*, which, it is hoped, will take part in the international co-operation, are distributed over the globe with a uniformity never before attained.

4. The *Observations*. All observations are simultaneous at all stations. They are of two kinds, viz.:—

(*a*) Hourly observations of the three elements on certain fixed term days, to determine the diurnal variations of the Earth's magnetism.

(*b*) Extended observations of the three elements during one hour agreed upon of each of the term days, to trace the course of individual disturbances.

Observations of the first class begin at 0 h. p.m., G.M.T., of a term day and end at 0 h. p.m. of the day following. At stations where the twenty-five hourly values of the three elements cannot be taken from the curves of self-recording instruments, readings of all three variation-instruments shall be taken precisely at each hour by three observers, but if only one observer is available the instruments shall be read successively as quickly as possible, in accordance with the following scheme:—

(x—1) h. 59 m. 30 s. G.M.T.	Declination. Vertical force. Horizontal force.
(x) h. 0 m. 30 s.	Horizontal force. Vertical force. Declination.

Observations of the *second* class will, where possible, consist of photographic registers of all three elements taken on quickly-moving cylinders running for about two hours, with a wide time-scale (about twenty-four cm. per hour). At stations without the necessary equipment the variation instruments shall be read every twenty seconds for a complete hour, in the same manner as in observations of the first class, according to the following scheme:—

(x) h. 0 m. 0 s.	Declination. Vertical force. Horizontal force.
(x) h. 0 m. 20 s.	Declination. Vertical force. Horizontal force and so on.
($x+1$) h. 0 m. 0 s.	Declination. Vertical force. Horizontal force.

It is to be specially noted that the period of vibration of the needle of an instrument should *not* be twenty seconds, or any aliquot part thereof.

5. *List of Term Days and Hours.*—All observations of the international co-operation shall be made according to Greenwich Mean Time.

Term days. Observations hourly from 0 h. p.m. to 0 h. p.m.			Term hours. Observations extended during the hour.
1902.	February	1	0 h. p.m. till 1 h. p.m.
		15	1 h. p.m. „ 2 h. p.m.
	March	1	2 h. p.m. „ 3 h. p.m.
		15	3 h. p.m. „ 4 h. p.m.
	April	1	4 h. p.m. „ 5 h. p.m.
		15	5 h. p.m. „ 6 h. p.m.
	May	1	6 h. p.m. „ 7 h. p.m.
		15	7 h. p.m. „ 8 h. p.m.
	June	1	8 h. p.m. „ 9 h. p.m.
		15	9 h. p.m. „ 10 h. p.m.
	July	1	10 h. p.m. „ 11 h. p.m.
		15	11 h. p.m. „ 0 h. a.m.
	August	1	0 h. a.m. „ 1 h. a.m.
		15	1 h. a.m. „ 2 h. a.m.
	September	1	2 h. a.m. „ 3 h. a.m.
		15	3 h. a.m. „ 4 h. a.m.
	October	1	4 h. a.m. „ 5 h. a.m.
		15	5 h. a.m. „ 6 h. a.m.
	November	1	6 h. a.m. „ 7 h. a.m.
		15	7 h. a.m. „ 8 h. a.m.
	December	1	8 h. a.m. „ 9 h. a.m.
		15	9 h. a.m. „ 10 h. a.m.
1903.	January	1	10 h. a.m. „ 11 h. a.m.
		15	11 h. a.m. „ 0 h. p.m.
	February	1	0 h. p.m. „ 1 h. p.m.
		15	1 h. p.m. „ 2 h. p.m.

The variation instruments should be placed in position and fully tested as long as possible before February 1, 1902, so that the following terminal observations may be made in January:—

1902.	January	1	10 h. a.m. till 11 h. a.m.
		15	11 h. a.m. „ 0 h. p.m.

6. *Special Observations on the Term Days.*—It is desired that special attention be devoted on the term days to observations of atmospheric electricity and appearances of the aurora.

7. *The Variation Instruments.*—For polar stations it is sufficient if the instruments are of such sensitiveness that one scale division, equal to one mm. of the ordinates of the curves, correspond to

For Declination	5 min. of arc.
Horizontal force	$10\,\gamma = 0{\cdot}00010$ C.G.S.
Vertical force	$10\,\gamma = 0{\cdot}00010$ C.G.S.

in units of the centimetre-gramme-second system. For stations in lower latitudes the following scale of sensitiveness is desirable:—

Declination	1 min. of arc.
Horizontal force	5 γ
Vertical force	5 γ

It is desirable that at temporary observatories the zeros of the instruments should be ascertained between the term days by means of absolute measurements, and the sensitiveness of the instruments should be tested several times a year.

8. *The Absolute Instruments.*—It is desirable that the permanent observatories, either before or during the period of joint observations, should carefully test the constants of their standard instruments, and make a fresh series of comparisons amongst themselves. The absolute instruments of the temporary observatories, which serve to standardise their variation instruments, must be compared with the standards at home before starting, and again after their return.

9. *Observation Forms.*—The office of the Seventh International Geographical Congress in Berlin will send a specimen of Observation Forms, in which the terminal observations are to be entered, to each of the co-operating stations.

V.

ANTARCTIC CLIMATE.

INTRODUCTION.

The meteorology of the Antarctic regions is practically unknown to science, inasmuch as only one expedition, that of the Belgian Government, in 1898–9, has been able to furnish observations for even one complete year.

The other expeditions, of which there have been five (including that of Ross, 1841–3), have only been able to supply records covering a few months, at best; and those generally not from a fixed station, as they were taken on board a ship at sea.

The *Belgica* was frozen up, and drifted more or less with the ice. Her movement covers eight degrees of longitude; but, as to latitude, which, as Dr. Supan justly observes, is most important, she only varied from 69° 50′ to 71° 30′, so that her observations are confined to a narrow belt.

The observations of Ross's expedition have already been discussed at the Meteorological Office—and published, in 1873, under the title 'Contributions to our Knowledge of the Meteorology of the Antarctic Regions'—so that it has not seemed necessary to reproduce them in this Manual.

As to the other information, the amount is so small that the best course appears to be to reproduce the several accounts in full, either as reprints from English journals or as translations from German sources.

The first paper given is extracted from 'Klimatologie,' by Hofrath Dr. Julius Hann, a work universally regarded as the most compendious and trustworthy in existence on the climates of the globe.

This is followed by a paper by Dr. W. S. Bruce on his observations in the whaler *Balæna* in 1892–3.

The next paper is a summary, by Dr. A. Supan, of the observations from the *Antarctic*. This ship was a whaler belonging to Mr. Sven, Foyn of Tonsberg. It was under the command of Captain Kristensen, and Mr. Borchgrevink shipped as one of the crew. It

left Melbourne September 20, 1894, and returned in March 1895, so that the observations represent only two months, December 1894 and January 1895.

The German *Valdivia* expedition is the next. The scheme for this voyage was laid before the meeting of the Deutsche Naturforscher und Aertzte, on August 1, 1898, by Professor Chun, of Leipzig. It was approved, and the German Government voted 300,000 marks (£15,000) in its aid. The steamer was chartered in Hamburg, and was under the command of Captain Krech. Dr. Chun was scientific director; and Dr. G. Schott, whose paper is reproduced, was oceanographer. The stay in high southern latitudes was not much longer than that of the *Antarctic*.

We now come to the Belgian expedition, which spent fourteen months within the Antarctic circle. Of this we have two accounts, one by Hofrath Hann and the other by Dr. Supan, and both are reprinted.

Lastly, we have the recent expedition fitted out by the liberality of Sir G. Newnes. The ship was called the *Southern Cross*, and the leader of the expedition was Mr. Borchgrevink. The observations have not been thoroughly discussed, so that all that is available is a preliminary notice by Mr. Bernacchi, meteorologist to the expedition, and that is what we reproduce.

ROBERT H. SCOTT.

FROM HANN.

(*Handbuch der Klimatologie*, 2nd Edition, 1897, vol. iii. p. 543.)

FOR the climate of the Antarctic zone we only possess a few incomplete observations, which have been obtained by various expeditions to those regions. Two peculiarities of the climate are strongly expressed, the very low summer temperature, and the extraordinarily low readings of the barometer. The observations of Sir J. C. Ross during the three famous expeditions to the South Pole in 1840–43 in H.M.SS. *Erebus* and *Terror*, and of Moore in the *Pagoda* in 1845, give for 64° 30′ S. lat. a mean summer temperature of 31°·1 (four months' observations, December to March, between 60° and 68° S.); and for February, between 75° and 78° S.,

* Not printed in the 'Meteorologische Zeitschrift.'

as low as 24°·1. These are the lowest summer temperatures we know of anywhere.*

For the pressure at sea-level in high Southern latitudes the same observations give the following mean values:

Latitude	60°–67°	65°–71°	70°–75°	75°–78° S.
Barometer	29·123	29·032	28·898	28·969.

Accordingly, the mean pressure here is as low as it is in the Northern Hemisphere in great depressions or during heavy storms.

This very low barometrical pressure in the Southern Hemisphere is accompanied by strong and almost constantly stormy Westerly winds south of the parallel of 40° S. The whole Antarctic circumpolar area presents us, as already stated, with a vast cyclone, of which the centre is at the pole, while the Westerly winds circulate round it. The universal water-covering of high southern latitudes, which opposes no obstacle to the uniform development of this rotatory motion in the lower strata of the atmosphere, is the cause of this rapid reduction of pressure with increasing latitude. In the Northern Hemisphere the continents do oppose such obstacles, owing to the independent circulations of the atmosphere to which they give rise.

The report of the voyage of the *Antarctic* in 1895 states: "The barometer within the Antarctic circle stood at 29 inches with calm fine weather, and even at 28 inches the weather was still fine." On the whole the weather in summer is generally reported as fine within the Antarctic circle, there is often a clear sky, a bright sun, a light wind, very little fog, but certainly frequent snow showers. The heavy stormy weather prevails outside the polar circle. The almost constant fog of the northern circumpolar area is nowhere to be found in the south.

This appears to indicate that a barometrical maximum must exist over the snow-covered Antarctic continent, if such a region exists. In the highest southern latitudes the prevalent winds are Southerly and South-easterly. The surface currents also come from a Southerly direction; the ice drifts towards the north-east. As long ago as in 1872 Neumayer put the limit of the "brave West winds" at about 62° S.

One, or still better, several winterings in high Southern latitudes

* The observations given in 'Contributions to our Knowledge of the Meteorology of the Antarctic Regions' show for December (/40–/42, 31 days), in 63° S., 32°·0; for January (/42 and /43, 62 days), in 65° 7′ S., 30°·7; for February (/43, 28 days), in 65° 5′ S., 30°·7); for March (/41 /42 and /45, 61 days), in 63° 6′ S., 30°·4. The later observations in the *Antarctic* give, according to Supan, for the beginning of summer, 32° in 66° S. Ross appears to have had cold years.

would enable us to solve some of the most important and interesting problems of scientific climatology. The knowledge of the winter temperatures in the polar region of a water hemisphere is at present the most pressing requirement of our science, as we have pointed out in vol. i. p. 209, etc.

The notice closes with references to papers by Neumayer, Supan, Murray and Dinklage, the last-named on the great ice-drift in the Southern Ocean since 1891, in the 'Annalen der Hydrographie,' 1893, p. 41, *et seq.*

Translation of a letter from Hofrath Hann to Mr. R. H. Scott, in reference to his remarks on the Antarctic Anticyclone ('Klimatologie,' vol. iii.).*

"As regards the Antarctic Anticyclone, I have certainly not expressed myself quite clearly in my 'Klimatologie,' as you very fairly point out.

"It is certain that an area of pressure, which is higher than that of the surrounding area, lying over a chilled continent, or over any considerable land area, can coexist with a great polar cyclone, for instance, round the South Pole. The very low temperature can produce in the lower strata of the atmosphere a pressure higher than its environment. The anticyclone, however, must be very shallow, and at a moderate elevation the ordinary circulation of the atmosphere must re-establish itself. Borchgrevink's observations at Cape Adare proved that pressure sank lowest in winter, and, accordingly, the pressure in the upper strata made its influence felt as the predominating one at the ground level. It is just possible that further inland a slight increase of pressure might be observable. There is certainly no chance of the existence of a real continental anticyclone, inasmuch as at Cape Adare the barometer falls from summer to winter.

"The barometer maximum which the South-east wind produces is evidently a very shallow one, confined to the lower strata, and is only to be detected as a reduction in the rate of decrease of pressure towards the pole. It is an interesting question, the solution of which will possibly be supplied by the forthcoming expeditions."

* Letter not dated, but received in December.—R. H. S.

METEOROLOGICAL REMARKS BY W. S. BRUCE ON BOARD THE "BALÆNA," 1892–93.

Weather.—The meteorological observations of the expedition are more complete than any other set of observations, and for general (though perhaps more for local) conditions we have some interesting notes.

Periods of calms and gales alternate in this part of the world. On Christmas Eve and Christmas Day there was a perfect calm ; the sky, except at the horizon, had a dense canopy of *cumulus* rolls, which rested on the summits of the western hills, and when the sun was just below the horizon, the soft greys and blues of the clouds and the spotless whiteness of the ice, as it floated in the black and glassy sea, were tinted with the most delicate of colours—rich purples and rosy hues, blues, and greens passing into translucent yellows. This was a very typical calm day, but there were also calm days with cloudless skies and brilliant sunshine. Should a gale blow from a Southerly direction, it was usually accompanied by snow, and if from a Northerly direction, by wet fog, as shown below:

FEBRUARY 8, 1893.

Time.	Wind Force 1–12.	Clouds, 0–10.	Weather.	Dry-Bulb.
1	N.W. 3	..	thick wet fog	32·3
8	N.N.E. 4 to 5	10	overcast; thick very wet fog, and raw	32·8
10	N.N.E.	10	overcast; foggy, raw, raining	31·9
12	N. by W. 2..	10	overcast; thick fog; very wet sky	33·4
16	S.W. 6 to 7..	10	overcast; misty round horizon	30·1
20	S.S.W. 10	10	overcast; snow showers since 6 p.m.	29·6
22	S.S.W. 10	10	overcast; snowing; coarse dirty night	29·2

On January 29, 30, 31, and February 1 we had a hard gale. It blew chiefly from the South, but backed and veered between South-south-west and South by East. At times on the 29th and 30th I have recorded wind of a force up to 10. On the 29th I have noted that this was pronounced by all to be the heaviest of all since we made the ice; on the 30th the skipper told us that had we been in the open ocean, with our vessel in good trim, she would scarcely have borne close-reefed topsails. From 10 p.m. on the 29th till 8 a.m. on the 30th we steamed full speed against the wind, and only made about

1 mile headway.* Snow was falling almost continuously, being very fine and slight. The thermometer fell from 31·7° F. to 27·7° F. Again on February 10 I have recorded a brief North-west and North-north-west gale, after which there were some hours of calm. The wind by 8 a.m. on February 12 had veered to South, force 1, and remaining South, increased to force 8 by 11 a.m., rising to a recorded 11 to 12 at noon. At 4.30 a.m. on the 13th it had not abated in the least; from 8 a.m. to 3 p.m. force 8 is recorded, and in the evening there was only a strong breeze. In this instance I must have recorded too great a force, according to some authorities, since I am here to tell the tale; but our captain described it as the hardest gale that ever blew in the Arctic or the Antarctic, and so hard that we could not have borne close-reefed topsails in the open. For part of the time thick fog prevailed, and fine snow was driven before the wind. The thermometer fell from 32·4° F. to 25·2° F. The barométer was lowest at 10 a.m. on the 12th, standing at 28·978 inches, and by 1 a.m. on the 13th had only risen to 29·057.

Observations were made every two hours as far as was possible, and have been grouped in twelve columns for each day. The mean of these has been calculated for every month, and again from these twelve means the mean temperature of the month has been obtained. In no case does the mean monthly temperature exceed that of the freezing-point of water. For the last two weeks of December it was 31·1° F., which was also the mean temperature of January, while that of the first eighteen days of February was 29·7° F. In the region traversed from lat. 61° S. to 64° 40′ S., and from long. 53° W. to 57° W., which may roughly be compared to that of the Faröes in the Northern Hemisphere, the mean air-temperature in the month of maximum temperature is half a degree below the freezing-point, instead of about 23 degrees above it. It may be assumed that January is the warmest month, since the observations made in December, while giving the same mean temperature, were obtained only in the latter, and presumably the warmer, fortnight of the month. Except for the rise at 6 a.m. in December, which is the mean of only two readings, and is therefore not considered, the two hourly mean temperatures cross the line of the melting of ice only at 4 and 8 p.m. in December, and at 2 p.m. in January, the mean maximum at 2 p.m. in February coming within two-tenths of it.

The warmest hours of the day (8 a.m. to 6 p.m.) averaged 31·5° in December, 31·4° in January, and 30·5° in February; while the night temperatures (8 p.m. to 6 a.m.) were 1·1° lower in January,

* Under most favourable conditions, calm sea and no wind, the vessel can steam 8 knots.

and 2·9° lower in February (the night means cannot be calculated satisfactorily for December).

The following table shows the maximum and minimum readings in each month and for the whole period:

	Maximum.	Minimum.	Range.
1892.			
December 16–31 ..	37·1°, noon on 16th	24·6°, 1.30 a.m. on 6th	12·5°
1893.			
January 1–31 ..	37·3°, 2 p.m. on 15th	27·7°, 8 p.m. and midnight on 30th	9·6°
February 1–18 ..	36·2°, 4 p.m. on 7th	20·8°, noon on 17th	15·4°

Hence the extreme temperatures recorded were—maximum 37·3° and minimum 20·8°, giving a range of 16·5° F.

As with temperature observations, pressure observations were made every two hours, as far as was possible, and have been grouped in twelve columns for each day. The mean of these has been calculated for every month, and the whole period mean has been obtained. The mean pressure for the last two weeks of December was 29·357 inches; for January, 29·273 inches; and for first eighteen days of February, 29·160 inches. There is thus a falling off in pressure from December to February, the mean for the whole period, December 16 to February 18, being 29·263 inches, or about half an inch lower than for the corresponding season in the Faröe Islands. All the means attain a maximum at 10 a.m. and 6 p.m., and all, except those for February, at midnight also. There seems to be a minimum period during the early morning hours. On the whole the pressure appears to be greater in the afternoon than in the forenoon; but the forenoon data are insufficient for obtaining reliable results.

The following table shows the maximum and minimum readings in each month and for the whole period:

	Maximum.	Minimum.	Range.
1892.	Inches.	Inches.	
December 16–31 ..	29·834, 6 a.m. on 16th	28·801, 8 a.m. on 20th	1·033 in.
1893.			
January 1–31	29·753, 4 p.m. on 2nd	28·745, 10 p.m. on 20th	1·008 in.
February 1–18 ..	29·750, 4 p.m. on 6th	28·850	0·896 in.

Hence the extreme pressures recorded were—maximum 29·834 inches, and minimum 28·745 inches, giving a range of 1·089 inch.

METEOROLOGICAL OBSERVATIONS MADE ON BOARD THE *BALÆNA* BY W. S. BRUCE, BETWEEN 60° AND 65° S., 51° AND 57° W.

Date.	Wind.		Barometer.		Thermo.		Weather.	Sea Surface.	
	Direction.	Force.	Barometer.	Att. ther.	Dry.	Wet.		Temp.	Sp. gr.
1892. Dec. 17	W.	3·3	29·445	58·67	35·55	35·22	F.	34·78	29·0
18	N.E. / W.	2·5 / 4·3	29·261	54·27	33·52	33·23	Fr.	32·50	29·5
19	N.W. / N.N.E.	1·9 / 4·6	29·278	48·97	34·00	33·72	O.F.	32·17	27·5
20	N.N.E.	2·6	28·962	49·28	33·95	33·63	F.	31·53	26·5
21	N.N.W.	1·7	29·104	45·83	32·97	32·33	F.	31·55	27·5
22	E.	1·5	29·091	48·67	32·28	31·67	F.	30·95	28·0
23	S.	2·2	29·264	51·47	33·42	32·45	O.G.	32·25	27·5
24	S.	2·0	29·470	49·48	32·84	31·80	C.B.S.	32·74	27·0
25	S.	0·3	29·689	49·30	32·53	31·45	C.B.	32·52	28·0
26	E.	2·3	29·763	51·05	30·15	29·48	O.	32·18	27·0
27	E.	5·0	29·595	47·75	31·15	31·20	O.G.	31·52	27·5
28	E.	4·6	29·509	41·13	31·27	31·27	O.G.M.	31·90	27·0
29	N.N.E.	3·6	29·499	48·15	31·32	31·32	O.G.	31·76	27·0
30	E.	2·0	29·548	49·35	30·14	30·25	O.	31·07	27·0
31	S.E.	1·6	29·584	47·08	31·65	31·10	C.B.	31·28	27·0
1893. Jan. 1	E. & N.	1·9	29·624	45·08	31·70	30·62	C.	31·58	27·5
2	N.	1·4	29·633	48·60	31·55	34·55	B.	32·33	27·5
3	N.E.	4·1	29·497	47·70	33·67	32·52	O.S., C.B.	31·87	27·5
4	N.E.	3·0	29·409	46·72	33·80	33·03	O.M.Q., 5 S.	31·92	27·0
5	Calm	0·0	29·512	48·70	34·76	34·00	O.	32·20	27·0
6	E. & N.E.	3·2	29·416	49·95	35·38	34·15	O.S.Q.	32·10	27·0
7	W.	0·8	29·481	50·40	35·00	33·64	O.S.	31·92	27·5
8	W.	1·7	29·424	51·67	34·73	33·88	O.M.F.	32·32	27·5
9	N.E. / N.W.	1·5 / 0·2	29·270	50·90	35·83	34·52	O.F.	33·08	27·0
10	S.	5·2	29·150	43·50	32·20	31·62	O.M., 10 S.	31·87	27·5
11	Calm	1·0	29·390	50·08	36·10	34·82	C.B.V.	32·34	27·5
12	N. / S.E.	3·4 / 1·7	29·241	48·82	33·28	32·55	O.S.	32·03	28·0
13	E. / Calm	1·4 / 0·0	29·379	49·54	33·02	32·12	O.F.	32·02	27·5
14	N.E.	1·2	29·604	47·27	35·05	33·28	C.B.	32·30	27·5
15	N.	2·1	29·685	48·77	34·57	33·40	B., F.	32·03	27·5
16	N.N.E.	2·9	29·655	44·27	31·72	31·15	F.	31·80	27·5
17	N.	3·8	29·682	46·03	33·50	32·75	O.M.G.	32·23	27·5
18	N.N.W.	3·6	29·452	46·63	34·15	33·78	F., O.M.G.	32·05	27·0
19	W.	4·2	29·051	44·83	33·03	32·17	O.G.M., F., IV., 6 S.	32·05	26·5
20	W.	2·9	28·934	46·20	34·22	33·80	O.F.G.	32·38	26·5
21	W. / S.	1·3 / 2·0	28·897	47·52	34·12	33·38	F., C.B.	32·88	27·0
22	W.	1·0	29·119	48·38	34·70	33·44	O.M., C.B.	32·74	27·0
23	Calm / E.	0·0 / 3·0	29·122	49·28	32·15	31·27	C.V., O. 3½ S.	31·42	27·0
24	E. & S.	3·8	28·741	48·88	31·87	31·35	O.M.S.	31·72	27·6
25	S.	3·3	29·105	48·30	32·02	31·63	O.M.D.	32·13	27·5
26	S.S.E.	1·5	29·415	48·92	32·77	31·85	O., C.B.	32·40	27·5
27	E.	0·7	29·563	45·00	32·78	30·93	C.B.	32·05	27·5
28	S. & E.	2·8	29·474	43·55	30·92	29·78	C.B.	31·62	28·0
29	S.	6·7	29·161	41·67	29·98	29·74	C.B.	31·28	28·0
30	S.	7·2	28·624	40·26	29·38	29·00	O., C.	30·80	27·5
31	S.	6·6	29·089	48·52	30·32	30·32	O.M., 11 S.	31·58	27·5
Feb. 1	S.	6·3	29·014	43·77	30·65	31·57	O.M., 10 S.	32·05	27·5
2	S.E.	2·3	29·165	47·80	31·28	31·08	O.	31·88	27·5
3	S.E.	2·5	29·128	49·14	31·46	30·78	O.V., O. 3 S.	31·50	27·5
4	S.E.	4·5	29·010	31·47	31·62	31·43	O.F., 16 S.	31·12	27·6
5	S.S.E.	5·2	29·299	45·40	31·28	31·06	O.M., 12 S.	31·27	27·2
6	S. / W.	2·6 / 2·2	29·723	44·13	33·22	31·86	C.B.V.	31·50	27·0
7	W.N.W.	2·8	29·399	46·23	35·05	34·23	O.F., 4 S., C.B.V.	31·73	27·3
8	N. / S.W.	2·1 / 7·0	29·099	46·80	30·48	31·88	O.F., 3 E.D., 4 S.	30·95	27·6
9	S.S.W.	4·4	29·520	44·50	31·18	30·55	O.M.	31·58	27·2
10	N.N.W.	3·4	29·433	45·57	33·73	33·49	O.M.	31·43	26·5
11	N.W.	2·7	29·254	47·72	34·62	33·93	B.C.F.	31·13	27·0
12	S.S.E.	5·4	29·141	43·35	29·24	28·90	O.F., 11 S.	30·76	27·0
13	S.	7·0	29·246	42·73	26·13	25·75	O.Q.S.	31·22	27·4
14	S.S.E. / N.W.	1·8 / 3·3	29·131	45·30	28·75	28·25	C.B., O.M.	31·82	27·0
15	E.	2·7	29·097	43·83	29·43	28·58	O.M., 10 S.	31·13	27·2
16	N.E. / S.E.	3·4 / 6·0	29·008	52·26	30·60	31·04	O.M., 5 S., LV., 4 D.	30·94	27·5
17	S.S.E.	4·6	29·152	42·92	24·12	24·17	C.	30·00	27·5
18	N.E. / N.N.W.	1·4 / 3·4	29·330	46·73	31·94	31·58	O.M.G.F.	30·68	27·4
19	N.N.W.	3·9	29·181	49·63	35·33	35·05	O.F., 11 D.	31·77	27·5
20	W.N.W.	2·7	29·101	48·27	33·28	32·77	F., 4 D., C.B.	31·32	27·0
21	W.N.W.	4·3	29·254	51·44	35·18	34·66	C.B.	31·34	27·2
22	N.W.	4·9	29·310	53·43	35·56	34·86	O.M.F.	31·26	27·0
23	N.N.E.	2·0	29·030	48·77	32·72	32·63	O.M.F.D., 8 V.	30·98	27·0
24	S.W.	5·3	28·848	44·50	30·30	30·05	O.M.F., LV., 4 S.	30·83	26·0
25	W.S.W.	2·6	29·184	53·13	33·73	33·57	O.M., C.B.	33·40	26·8
26	W.S.W. / W.N.W.	4·9 / 4·0	29·542	55·68	38·55	37·92	C.B., O.M., 1 V.	36·82	26·5

THE METEOROLOGICAL OBSERVATIONS OF THE "ANTARCTIC" IN THE SOUTHERN POLAR SEA, 1894–1895.

(*Meteorologische Zeitschrift*, vol. xiii. 1896, p. 111.)

The meteorological observations of the last South Polar Expedition are about the most important of the results which have been secured.

The log has been reproduced by photolithography, and of this a specimen has been reprinted in Petermann's 'Mitteilungen.' The observations cover the months of December 1894 and January 1895, and were taken six times per day, but they are unfortunately incomplete. Here and there mistakes have occurred either in observing or copying. The temperatures are in whole degrees F., and the barometer was only read to tenths of an inch.

Air Temperature.—South of latitude 60° the temperature ranged between 43° and 27°. Ross, in the same region, in the first three months of 1841, had recorded 41°·5 and 11°·7. Hann had calculated from Ross's observations, for the zone 60° to 68° S. a mean temperature for summer of 30°·5, and for the zone 75° to 78° S. a mean February temperature of 24°·1. We may therefore assume from the log of the *Antarctic* that Ross's mean values are decidedly below the normal. From the latitude 66° S., where the *Antarctic* remained from December 15 to January 5, if we neglect the obviously incorrect observations for December 23, we can draw a fair diurnal temperature curve, and from this determine the 24-hour value. This is 32° (in the beginning of summer!) with a range of 2°·2 (31°·1 at 4 a.m., 33°·3 at 4 p.m.). The *Antarctic* remained in the belt of latitude between 70° and 74° from January 15 to 26. If we omit the figures for 4 p.m. we can get a good curve, and for a 24-hour mean the value 31°·6, with a range from 33°·3 to 30°·4. Ross was in these latitudes from January 10 to 21, 1841. The mean of the extremes was then 29°·7 (absolute maximum 40°·5, minimum 26°·4). If we remember that 1841 belonged to a cold climatic period, and that we are probably in a warm one at present, we may fairly frame the hypothesis that the normal mean for the summer lies between the values of Ross and Kristensen.

Temperature of Sea Water.—We need not reproduce these figures, inasmuch as they show a very uniform condition. We may, however, point out the distinction between different belts of the Southern Ocean as follows:

1. In the northern belt the following surface temperatures were observed at noon:—

54° 33′ S. . . .	48°·0
56° 41′ . . .	44°·1
58° 47′ . . .	39°·9
61° 11′ . . .	37°·9

2. From 63° S. temperatures below 32° were observed, and up to the parallel of 66° almost all the observations lay between 28° and 30°.

3. Inside the belt of pack-ice, between 66° and 68° S., the water showed a constant temperature of 28°·0.

4. Between 68° and 70° S. the records ranged between 28°·9 and 28°·0.

5. Within the Antarctic circle the sea had a constant temperature of 28°·9. In the same latitude and at the same season, Ross had a mean value of 29°·1.

Pressure.—The barometer readings need some correction, and it would be very desirable to have them discussed. The maximum observed within the polar zone was 29·30 ins., and the minimum 28·10 ins. The persistent low pressure in high latitudes round the South Pole is, therefore, confirmed by this expedition.

Winds.—The force is regular, and the direction seems to have been recorded regularly. Of the former we give daily mean values in the general table. If we reduce these to eight points we obtain the following short table:—

Frequency Percentages.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	CALM.	TOTAL.
December (4–31) ..	4·3	3·5	2·8	0·0	8·2	16·3	35·8	19·1	10·0	100·0
January	9·0	7·3	17·8	4·5	17·3	8·2	19·5	6·2	10·2	100·0
Mean Force (0–10).										
December (4–31) ..	4·5	3·0	2·8	—	2·9	4·6	4·3	4·2	..	..
January	2·6	3·3	6·0	3·9	4·4	3·8	5·0	3·4	..	..

The change which took place between December and January is remarkable; the Westerly equatorial winds gave way to Easterly polar winds, and at the same time the force increased considerably. In January anticyclones seem to have appeared frequently in the south-east, and this seems to indicate the presence of a land area covered with ice.

Weather.—The suggestion which has just been expressed is confirmed by the fact that, as a rule, clear weather came with Southerly and Easterly winds. In December there were eight "clear" days,

and as many "partially clear." In January the "clear" days reached the total of thirteen, and five were at least "partially clear." Rain was last observed on December 5 in lat. 63° S. After that date precipitation was always in the solid form. December had four, January twelve days of snow.

SUPAN.

METEOROLOGICAL OBSERVATIONS ON THE GERMAN "VALDIVIA" EXPEDITION.

(From *Geographical Journal*, vol. xv. p. 527.)

THE meteorological equipment had been supplied from the "Seewarte" at Hamburg. A meteorological journal was kept, the observations being registered every four hours (day and night) by the officer on the bridge. Besides these important observations, we had three registering instruments, a thermograph, a hygrograph, and a barograph (by Richard Frères), which showed themselves very correct during the entire voyage. Thus for every hour of our way we shall be enabled to give the most important climatic elements. A hygrograph, especially in the high Southern latitude, is, perhaps, a new thing at sea.

The variations of the barometer in the squalls of the Tropics, at the change of the winds, etc., have been observed, and some observations of insolation and radiation have been made, besides measurements of the amount of rainfall, etc.

I will here describe only the state of the weather near the ice-limit, as we know it for a relatively large distance from 0° to 60° E. long. Here the limit between the stormy region of the "brave West winds" and the light East winds south of about 55°–57° S. lat. has a particular interest.

When we left Cape Town in November, on a South-south-west course, we had variable and often stormy weather, frequently a heavy sea, and sometimes heavy storms from the West-north-west. Not later than near Bouvet Island we got temperatures of the water of 30° F. and of the air under 32° F.—that is to say, in the southern summer and in a latitude like the northern part of England. Add thereto a continuous storm from North-west or West-north-west, and you may see that it was terrible weather; the deck was frozen or

covered with slush and ice. When going along close to the ice during the next three weeks we got continually an air-temperature under 32° F.; the minimum was only 27°·5 F., but this was sufficient to produce some disadvantages. The pumps, the fresh-water tanks, the steam-pipes which supplied one of the sounding-machines, were frozen, and sometimes the ship was totally covered with snow, as in the hardest winter.

As to the details, we got the West winds up to about 20° E. long., in 55½° S. lat. On December 4 we seemed to lose the stormy West winds and to reach their polar side, for the character of the weather for the entire distance from 20° to 60° E. long. to 65° S. lat. was totally altered. We had light winds, mostly from the East, of force 1–3 of Beaufort's scale at most, with calms and often perfectly smooth sea, not even a ripple, on December 5, 6, 7, 8, 10, 11, 12, 14, 15, 17, 21; that is, on 70 per cent. of the seventeen days we spent South of 55° lat. On the remaining 30 per cent. of those days we had moderate to strong winds, but also from the East, North-east and North, and even storms from the East; at any rate, no sign of West winds during all these weeks.

This weather by itself was favourable for our work, but the frequent fog and overcast grey sky prevented us sometimes, on the other hand, from going on. As soon as we had passed 55° S. lat. on our way northward, this time to the East, in the longitude of Kerguelen, we again met with the stormy West winds, and Westerly storms accompanied us up to Kerguelen. There remains still one remarkable thing, that is, the change of the barometer. You might expect that, beyond the stormy West winds, that is, south to about 55° lat., in the light East winds and good weather the barometer rose again, and that we had a relatively high pressure of the air. To my surprise, we got the following results from the registering instrument:—

Within the West-wind region, mean, 29″·51; and in their Western part (Bouvet), 29″·63; and in their Eastern part (Kerguelen), 29″·40,

Within the East-wind region, mean, 29″·32.

The most Southerly regions had the lowest average of atmospheric pressure; we have not yet found a rising of the barometer towards the pole or a trace of an Antarctic anticyclone, not even near Enderby Land.

G. Schott.

THE BELGIAN EXPEDITION.

See also **Henryk Arçtowski, 'The Antarctic Climate,'** ***Geographical Journal,*** **vol. xiv. (1899) p. 413.**

Preliminary Results of the Meteorological Observations of the Belgian Antarctic Expedition.

I. *Pressure.*—M. Arçtowski, Meteorologist and Geologist to the *Belgica*, has published in 'Ciel et Terre,' No. 12 (26th year), August 16, 1899, the most important results of his observations. This expedition has had the merit of supplying to science the first complete year's records from the Antarctic regions.

The following figures for pressure are quite approximate, being taken from aneroid readings and without any correction for temperature. We shall, therefore, confine ourselves to reproducing the most important figures:

Pressure Means and Extremes (March 1898–Feb. 1899). 28 ins. +

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1·422	1·029	1·190	0·961	1·382	2·508	1·441	1·418	1·351	1·319	1·371	1·457	1·319
1·953	1·674	1·741	1·678	2·091	2·335	1·981	2·134	1·835	2·111	1·690	1·831	2·335
0·894	0·406	0·548	0·138	0·752	0·882	0·812	0·182	0·319	0·430	0·792	0·957	0·138

Range.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1·059	1·268	1·198	1·539	1·339	1·453	1·169	1·953	1·516	1·681	0·898	0·874	2·197

For February and March there are two years' observations. The absolute maximum, 30·335, on June 11, 1898, and the absolute minimum of 27·965 on March 2, 1899, both values reduced to 32° (but not so the means). The correction for gravity, which has not been applied, is about + 0·063 inch. The absolute range was 2·379 inches. The mean of the monthly ranges is 1·358 inch. The means for the seasons are: Summer, 1·067; Autumn, 1·358; Winter, 1·524; Spring, 1·150; so we see that the great variations of pressure extend to beyond the parallel of 70° S.

The mean pressure shown by the observations cited above is

higher than was to be expected from the three years' observations of Ross (but certainly the results given above are only approximate). Ross gives as means for the summer in 66° S., 29·123; in 74° S., 28·993; the Belgian figure (also for the summer, in about 70° S.) is 29·300. As the variations of pressure in the several seasons are considerable, we must wait for the results of the projected expeditions before we can come to any definite conclusions as to the increase of pressure in the highest Southern latitudes.

M. Arçtowski concludes from the monthly means that the annual curve shows maxima at the solstices, and minima at the equinoxes. Such a curve would not be so improbable, for the normal, or theoretical, winter minimum of the circumpolar region is masked by a maximum at the time of greatest cold, in the lowest strata, so that the only minima which remain are in spring and autumn. In this case, too, we must wait for further observations.

The calculated annual range is as follows:

$$29\cdot320 + \cdot137 \sin(216^\circ\cdot8 + x) + 0\cdot150 \sin(135^\circ\cdot0 + 2x).$$

II. *Temperature of the Antarctic Winter.*—The Belgian South Pole Expedition has supplied us with the first data about the winter temperature of the Antarctic regions, a subject which has excited very great scientific interest, inasmuch as hitherto we have had nothing but summer temperatures from high Southern latitudes. The mean of the twenty-four hourly observations have been as yet only approximately calculated. The results are as follows:

TEMPERATURE IN SOUTHERN POLAR SEA, MAR. 1898 TO FEB. 1899.
(70°–71° S. lat., 85°–95° W. long.)

OBSERVED MEANS.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
29°·8	30°·2	15°·6	10°·8	20°·3	4°·1	−10°·3	11°·7	−1°·3	18°·0	19°·8	28°·0	14°·7

YEARLY MEAN, SMOOTHED, FIRST APPROXIMATION.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
28·9	29·8	24·8	13·4	6·1	0·7	0·7	4·3	7·2	13·6	18·7	24·3	14·7

MONTHLY MINIMA.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
17·4	14·7	−4·5	−15·7	−13·2	−22·0	−34·8	−21·3	−45·6	−15·2	− 6·5	5·9	−45·6

The monthly maxima are, unfortunately, not given, as "they are of less interest." In the winter, maxima of 30° to 32° were noted; in summer these figures rose to 34° or 36°; so that the range is very slight.

Inasmuch as the monthly means for the one year's observations show a very irregular course, as is usually the case with observations from the sea at high polar latitudes, I have attempted to obtain the equation of the yearly march of temperature. I have carried out the calculation to the fourth term, but have convinced myself that it would be best to stop at the second term, and have accordingly done so.

The annual equation for the temperature is, accordingly,

$$14^{\circ}\cdot 7 + 14^{\circ}\cdot 2 \sin (86^{\circ}\cdot 2 + x) + 2^{\circ}\cdot 2 \sin (3^{\circ}\cdot 1 + 2x).$$

By means of this formula I have calculated the monthly temperatures, which may be taken as the most probable temperature means.

The winter is relatively mild for high latitudes, but the summer very cold, just as Nansen found it in the Arctic Ocean, but in a latitude ten degrees higher. The winter minimum of − 45°·6 was recorded at 4 a.m. on September 8, and is unexpectedly low.

The mean temperatures for the seasons are:

	Summer.	Autumn.	Winter.	Spring.	Year.
Observed	29°·3	15°·6	1°·8	12°·0	14°·7
Calculated	27°·7	15°·4	1°·9	11°·8	14°·7

The annual range of temperature should be 29°·2, but the observed range 40°·5 is certainly much greater.

The projected expeditions from Germany and England ought to supply us with more precise data as to the winter temperatures of high Southern latitudes.

J. HANN.

THE FIRST METEOROLOGICAL COMPLETE YEAR FROM THE SOUTH POLAR REGIONS.

BY DR. SUPAN.

(Meteorologische Zeitschrift, vol. xvii. pp. 220–223.)

I HAVE taken M. Arçtowski's figures and have somewhat condensed them, and have brought them together in a modified form in the subjoined tables, and it has appeared to me advisable to reduce

the wind directions to eight points, and to treat calms and winds separately. It is not without a feeling of reverence that we regard these simple rows of figures, which give us the first glimpse into the physics of the mysterious Antarctic area, and not merely into its meteorology, for they put us in a position to draw far-reaching conclusions, as we hope to show further on.

It was a circumstance particularly fortunate for the scientific observations that the Belgian ship was all but icebound for a whole year. The longitudes vary from 87°–95° W., but the latitudes (which is most important) varied only from 69° 50′ to 71° 30′, so that the meteorological observations have almost the same value as if they had been taken on land. The mean latitude is 70° 40′: the mean temperature of this latitude in the Northern Hemisphere is 14°·2 according to Spitaler, or (if we take account of the isotherms for Greenland, as corrected by Mohn) 13°·6; and is therefore not materially discordant from the Belgian station, which is 14°·5. For the parallel of 70° S. Hann has calculated an annual temperature of 23°, on the hypothesis of an ocean free from ice; it can therefore be seen how the ice modifies the conditions. We can certainly now maintain that the favourable thermal conditions of the Southern Hemisphere, which are clearly manifested between lat. 50° and 55°, thanks to the extension of open sea, are again lost as we approach the pole. This comes out even more clearly if we compare the two hemispheres. The parallel of 70° N. runs over vast continents, while the Belgian station lay over the open sea.

By using Spitaler's Tables we can calculate the mean temperature of 70° N. and thus obtain:

		Year.	Coldest Month.	Warmest Month.
		°	°	°
70° N.	Atlantic and Asiatic Arctic sea, 20° W.–75° E.	28·4	14·9	43·5
	American Arctic sea, 160° E.–55° W.	8·8	– 22·0	41·0
	Entire Arctic sea	18·1	– 4·2	42·3
70° S.	87°–95° W.	14·7	– 10·3	30·2

The difference between the Arctic and the Antarctic climates is very striking, and its explanation is to be found in the system of the Antarctic winds. The Belgian station lay in winter in the region of Westerly winds, in summer in that of Easterly, and this change had such a decidedly Monsoonal character that we may fairly suppose that the weather phenomena of the year of observation exhibit the

type of the climate of the region. This result is of the highest importance. If the surface of the Antarctic (i.e. the area portion bounded by the Antarctic circle) were approximately homogeneous, that is if the Pole lay in the centre of a continent, or if there were only very small islands, the centre of the South Polar anticyclone would lie persistently over the pole, and the system of Polar winds would extend itself uniformly on all sides, in winter naturally further than in summer, and the data from the Belgian expedition would give us a picture the exact opposite of what they do; there would be Easterly and Southerly winds in winter, Westerly and Northerly in summer. But the anticyclone itself is subject to shiftings in the course of the year; in winter it moves further towards the Eastern Hemisphere, and for this we can assign no other explanation than that a cold centre must lie on that side, towards the Indian ocean. But such a centre can only develop itself, apart from the Pole, over large areas of land. Accordingly we find in the Belgian winter observations a new argument for the idea, that the Antarctic land area belongs chiefly to the Eastern Hemisphere, where most topographical indications of a continent are presented to us by Victoria Land and Wilkes Land.

In winter therefore the Belgian station lay in the zone of the South Polar depression: and this is further proved by the fact that the non-periodic barometer oscillations reached their greatest amplitude at that season.

On the other hand, the curve of pressure for the year shows a character quite different from that of the depression in the Northern Hemisphere up to 70° N., for the barometer was lower in summer than in winter, so that apparently the Southern edge of the depression was not very far distant from the station. Despite the prevalence of Equatorial winds the winter was very cold, partly owing to the frequency of calms, but principally because the oceanic area from which the winds came has no Gulf Stream to warm them. Circumstances as favourable as those which are found in the North Atlantic Polar Sea do not occur elsewhere on the surface of the Earth.

Spring and summer are in fact times of transition. They are characterised by the struggle for mastery between the Equatorial and Polar winds. This explains the irregularity of the annual curve, the abnormal cold of April and September, and the abnormal warmth of May.

The predominance of the Polar winds in summer is even more strongly marked than that of the Equatorial in winter.

The low temperature is not so very surprising for the Antarctic

	Temperature.		Pressure.		Wind Frequency Percentages of all Observations.							
	Mean.	Abs. Min.	Mean.	Abs. Range.								
1898	°	°	ins.	ins.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
March	15·6	− 4·4	29·19	1·40	5	12	18	11	16	15	17	6
April	10·8	−15·7	28·96	1·54	8	6	20	21	11	7	13	14
May	20·3	−13·4	29·38	1·34	30	20	6	4	2	1	16	21
June	4·1	−22·0	·51	1·46	5	8	9	7	5	15	38	13
July	−10·3	−34·8	·44	1·17	5	1	11	18	19	15	22	9
August	−11·7	−21·3	·42	1·96	9	9	7	6	3	12	30	24
Sept.	− 1·3	−45·6	·35	1·52	12	19	14	8	11	11	16	9
Oct.	18·0	−15·3	·32	1·69	12	10	8	3	9	18	22	18
Nov.	19·8	− 6·5	·37	0·90	11	22	24	7	7	11	11	7
Dec.	28·0	+ 5·9	·46	0·87	2	16	26	18	7	16	12	3
1899												
Jan.	29·8	+17·4	·42	1·06	2	30	32	19	9	6	2	0
Feb.	30·2	+14·7	·00	1·30	9	18	28	22	7	4	8	4
Autumn	15·6	−15·7	·18	1·96	15	13	14	12	10	8	15	13
Winter	19·8	−34·8	·46	2·16	6	6	9	10	8	14	31	16
Spring	12·0	−45·6	·31	1·80	11	16	15	6	9	14	17	12
Summer	29·3	+ 5·9	·29	1·67	4	22	29	19	8	9	7	2
Year	14·7	−45·6	29·32	2·20	9	14	17	12	9	11	17	11

conditions, but it furnishes us with a very interesting problem if we compare the results with those from the Arctic regions. It is a well known fact that at all land stations in the North Polar regions, up to lat. 82°·5 N., we have summer temperatures above 32°, even with the stations on the edge of the inland ice of Greenland; in every place the influence of the land from which the snow has gone makes an impression on the temperature of the lower strata of the atmosphere. In the ice of the sea it is different, as we see from the observations from the *Fram*, in Nansen's account of his journey (2nd edition).

There we find:—

	Mean of warmest month.	Mean of summer.
1894 in 81° lat. N.	32°·5	30°·6
1895 „ 84°·0 „	31°·5	28°·8

These temperatures are, considering the latitude, incomparably higher than those of the *Belgica* in lat. 70° S. We might suppose

that the surrounding land must contribute to raising the temperature over the inner part of the Arctic Sea, but that ought to manifest itself by great contrasts in the thermal wind-rose, but according to Dr. Mohn's lecture at the Geographical Conference at Berlin, no such contrasts are discoverable. The summer temperatures from the *Fram* are therefore the correct ones for the North Polar regions, and are not seriously affected by winds, and we must look for another cause for the very low temperatures of the Antarctic summer. This cause

	Calms. Percentages of all Observations.	Number of Days with				
		Light Winds, not above Force 1.	Overcast or Fog.	Clear for several Hours together.	Snow.	Rain.
1898						
March	9·1	..	6	15	13	..
April	9·1	2	10	14	22	..
May	9·1	3	15	8	30	4
June	7·2	3	5	16	24	..
July	25·3	15	7	22	14	..
August	8·9	3	9	15	26	1
September	19·3	7	9	14	19	..
October	10·1	4	16	12	25	2
November	16·8	8	13	10	25	..
December	14·2	4	9	13	18	..
1899						
January	5·9	5	17	6	19	4
February	3·1	1	21	1	22	3
Autumn	9·1	5	31	37	65	4
Winter	13·9	21	21	53	64	1
Spring	15·3	19	38	36	69	2
Summer	7·9	10	47	20	59	7
Year	11·6	55	137	146	257	14

must be the Antarctic continent, which must be entirely covered with ice, the low summer temperature of which is carried far and wide over the ocean by the Polar winds. Land-ice and sea-ice behave themselves, contrary to the usual ideas, very differently as regards their summer conditions. The sea-ice breaks up into floes, while the land-ice remains always a compact mass.

Accordingly we find in the summer observations a new confirmation of the supposed Antarctic continent, and we may fairly expect that, owing to the very slight rise of temperature in summer, we

shall find there the absolutely lowest yearly temperature, the absolute Pole of Cold on the Earth.

It also comes out from Arçtowski's tables that the sea climate of the Antarctic regions is unpleasantly characterised by strong winds, long continued fogs, heavy clouds and frequent downpours. The winter is the best time: calms are frequent, and the number of days on which the sky is clear for hours together reaches its highest figure. In all these particulars which affect so materially the personal sensibility to temperature, the summer shows us an exact contrast to the winter. The material is not sufficient for a thorough investigation of the Antarctic climate; and we must particularly regret that the figures for pressure have not been corrected.

SUPAN.

METEOROLOGICAL OBSERVATIONS ON THE "SOUTHERN CROSS" EXPEDITION TO THE ANTARCTIC, 1899–1900.

By LOUIS BERNACCHI.

(From *Geographical Journal*, vol. xvi., 1900, pp. 404–408, also p. 569.)

THE following is an outline of the meteorological and magnetic observations taken by the expedition in Southern latitudes. The observations being still unreduced, it is impossible to discuss them fully at present, and for this reason no readings of the barometer can be given in this report. These meteorological observations were taken at Cape Adare in lat. 71° 18′ S., during an entire year, from February 1899 to February 1900. They were conducted on nearly the same lines as at a station of the First order, and as accurately and regularly as possible. During the nine months of the year readings were taken two-hourly, from 9 a.m. to 9 p.m.; and during the three winter months, June, July and August, two-hourly observations were made day and night. Besides these readings, and those of maximum and minimum thermometers, the self-registering instruments furnished barograph and thermograph curves for the whole period, and records of the amount of sunshine were made by the Campbell-Stokes sunshine recorder. The tables given below, although only first approximations, are sufficiently exact to indicate the general nature of the climate. Observations taken at Cape Adare are possibly

affected to a certain degree by local accidents, such as the contour of the country and proximity to the sea; but the record for the year has the great advantage of being taken at one spot.

Meteorological observations were taken on board ship every two hours, night and day, during the month (January 1899) she was beset in the ice-pack. The geographical area over which the observations were taken was between the parallels of 63° 38′ S. and 66° 46′ S., and the meridians of 160° 6′ E. and 166° 56′ E.

The mean temperature of the air for January was 29°·94 F., and of the sea 29°·64 F.; the mean temperature for the second week being the highest in both cases, as is shown by the following table:

TABLE I.—WEEKLY MEAN TEMPERATURES FOR JANUARY 1899.

	Mean temperature of air.	Mean temperature of sea.
	° F.	° F.
First week	30·2	29·8
Second week	31·9	30·1
Third week	29·4	29·5
Fourth week	28·4	29·2

The lowest temperature for the month, which occurred on the 29th, at 3 a.m., was 16°·8 F. (− 8°·8 C.) in lat. 66° 45′ and long. 165° 25′ E., off one of the Balleny Islands. The highest temperature for the month was 36°·4 at 5 p.m. on the 12th, lat. 65° 3′ and long. 161° 42′ E. The mean diurnal oscillation of temperature for the month was 5°·20 F. The greatest range between the maximum and the minimum of one day was 16° F., the least 1° F.

Light and variable winds prevailed during most of the month; the force was rarely greater than 4, Beaufort's scale. Gales blew on the 9th, 16th, 22nd and 23rd, when the velocity of the wind exceeded 30 miles an hour. The weather may be summarised as 5 days' clear bright sunshine; 13 days' snow and sleet; 2 days' rain, when the temperature rose above 32°; 4 days' mists and fogs; and the rest overcast.

As will be seen from Table II., the mean temperature at Cape Adare is above zero for six months of the year, and for six months below zero.

August was the coldest month, the mean temperature being − 13°·4 F. (− 25°·2 C.). The extreme minimum temperature

TABLE II.—MONTHLY MEAN TEMPERATURES.*

Month.	Mean Temperature.	Date of Maximum.	Maximum.	Date of Minimum.	Minimum.	Range.
	° F.		° F.		° F.	° F.
1899.						
February	26·4 †	..	..	..	..	..
March	17·7	5th	31·1	25th	− 2·5	33·6
April	10·3	2nd	30·0	19th	−10·0	40·0
May	− 4·6	4th	23·2	13th	−31·1	54·3
June	−11·8	11th	14·1	3rd	−36·0	50·1
July	− 8·6	18th	23·8	9th	−39·9	63·7
August	−13·4	15th	18·9	4th	−43·1	62·0
September	−11·9	7th	11·5	30th	−36·1	47·6
October	− 1·8	15th	19·6	2nd	−35·5	55·1
November	+17·8	25th	45·7	1st	− 4 0	49·7
December	31·8	25th	42·2	11th	+20·4	21·8
1900.						
January	33·0	23rd	48·9	10th	22·5	26·4

Mean temperature for the year = 7°·05 F.

occurred on August 4, at 9 p.m., during perfectly calm and clear weather. Table III. shows the fall of temperature during the afternoon of that day, with the accompanying barometric pressure:

TABLE III.

Time.	Temperature.	Temperature.	Barometer (corr.).
	° F.	° C.	inches.
1 p.m.	−36·0	−37·8	29·292
3 „	−40·0	−40·0	29·312
5 „	−41·5	−40·8	29·324
7 „	−42·0	−41·1	29·344
9 „	−43·1	−41·7	29·355

At these temperatures the mercury froze in the ordinary thermometers, and spirit ones had to be used. The above temperatures are means derived from three thermometers. At these low temperatures there was a slight diversity in the indications of the respective thermometers, even after applying the corrections as given upon the Kew certificates. The maximum temperature observed at Cape

* Obtained by taking the means of maximum and minimum daily temperatures.

† Based on twelve days' observations, 16th to 28th.

Adare, 48°·9 F., occurred during a very heavy storm from the East-south-east, on January 23, 1900; but this is quite exceptional. The mean monthly temperature is above freezing-point during one month of the year, viz. January.

The relatively high mean temperature for July is due to the number of gales from East-south-east and South-east during that month, the temperature invariably rising with these winds. The extreme range of temperature was 92° F., and the mean temperature for the year + 7°·056 F. (– 13°·9 C.), which compared to the mean annual temperature for the same northern latitude, is extremely low. The mean temperature for Lapland, in 71° N., is about 32° F., and the mean temperature for the north of Spitsbergen, which extends as far north as 82° N., is about 10° Fahr.

The temperature of the sea during the greater part of the year, that is, while the surface of the sea is frozen over, remained constant at 27°·8 F. In the summer months, December, January and February, it rarely rose above 32° F.

During the winter months, or at least during the seventy-one days that the sun remained constantly below the horizon, the diurnal variations of the thermometer and barometer were scarcely perceptible, being almost, if not quite, concealed by the oscillations due to the passage of storms.

The intensity of solar radiation was measured with the black-bulb thermometer *in vacuo*. This instrument was freely exposed to the sun by fixing it horizontally above the ground at the same height as the thermometer screen, viz. 4 feet 6 inches.

A temperature above 80° F. was frequently recorded by this thermometer, while the temperature in the shade remained below freezing-point. These high readings were probably due to the hygrometric conditions of the atmosphere, the air, on account of the intense cold, being extremely dry.

Table IV. gives some of the highest readings with the solar radiation thermometer and the temperature of air in the shade observed at the same time.

The most remarkable feature in the meteorological conditions of the Antarctic is the wind. The prevailing East-south-east and South-east winds at Cape Adare, which is within the area of abnormally low pressure, tend to prove the existence of a great anticyclone stretching over the Polar area, which in its turn necessarily implies the existence of upper currents from the Northward, blowing towards and in upon the Polar regions to make good the drain caused by the surface outblowing South-easterly winds. The frequency and force of

TABLE IV.

Date.	Solar thermometer.	Temperature in shade.
	° F.	° F.
March 3	88·0	24·0
„ 6	92·0	22·4
„ 14	88·3	20·9
„ 16	92·2	24·5
„ 26	104·2	8·0

Relative humidity between 40 and 50 per cent.

these gales, and the persistency with which they blew—always from the same direction, East-south-east—the invariably high rise in the temperature, and the sudden fall and rise of the barometer, the dryness of the winds—the relative humidity generally between 40 and 50 per cent.—and the motion of the upper clouds from the North-west, point to the fact that the South Pole is covered by what may be regarded practically as a great permanent anti-cyclone, more extensive in the winter months than in the summer. Nothing more appalling than these frightful winds, accompanied by tons of drift-snow from the mountains above, can be imagined. On ninety-two days, or 26 per cent. of the time spent at Cape Adare, the wind blew from the East-south-east and South-east with a velocity above 40 miles an hour, and on one or two occasions above 90 miles an hour, at which stage our Robinson anemometers were demolished. A proper table of wind directions, velocities, and thermal wind-roses is not available, but the following tables will suffice to convey some idea of the conditions.

TABLE V.—NUMBER OF DAYS IN EACH MONTH WHEN VELOCITY OF THE WIND WAS ABOVE 40 MILES AN HOUR.

	Month.	Number of Days.
1899.	February	5
	March	11
	April	8
	May	7
	June	7
	July	12
	August	6
	September	6
	October	7
	November	5
	December	9
1900.	January	9

Table VI.—Conditions during a Storm on April 2, 1899.

Time.	Barometer (corrected).	Temperature of air.	Direction of Wind.	Velocity of wind.
April 1—	Inches.	° F.		Miles per Hour.
9 p.m.	29·599	12·2	W.	5·7
April 2—				
9 a.m.	29·199	17·0	Whirlwinds.	..
11 a.m.	29·064	22·6	E.S.E.	82
1 p.m.	28·919	24·0	E.S.E.	83
3 p.m.	28·916	26·9	E.S.E.	102?
5 p.m.	28·880	24·3	E.S.E.	88
7 p.m.	28·880	25·3	E.S.E.	90
9 p.m.	28·917	27·9	E.S.E.	82·5
April 3—				
9 a.m.	29·208	19·5	S.	40·6

The maximum temperature during the gale was 31·5° F. During a gale on March 19 a Robinson anemometer was demolished, the velocity of the wind exceeding 90 miles an hour; and another was destroyed on the night of May 18, when it was impossible to estimate the velocity of the wind. The anemometers used were tested at the Kew Observatory prior to the departure of the expedition from England, and were found to give results within 97 per cent. of the Kew instruments. It is evident, however, that the action of wear and tear on the instrument by these gales must have a very material influence on its indications.

The barograph and thermograph curves during a storm from the East-south-east on May 14, 1899, show very clearly that the temperature commences to rise before the barometer commences to fall; indeed, it was often possible to predict an approaching gale by the thermometer alone, long before the barometer showed any sign of the disturbance.

The mean barometric pressure for the winter months is much lower than the mean for the summer, but the means have not yet been determined. The highest barometric pressure occurred on July 22, 1899, when the barometer registered 30·182 inches, and the lowest, 27·860 inches, on September 9, 1899.

On the journey from Cape Adare southwards, some remarkably low temperatures were observed for the time of the year. Thus, off Mount Erebus on February 11, 1900, the temperature sank to − 6° F. with a wind from the South straight off the great ice barrier. Again, on February 19, the minimum temperature was − 12° F.

(– 24°·4 C.), with clear sky and light wind from the South. It is possible to form an idea from these temperatures what one would be likely to encounter in the way of cold on a sledge journey Southwards from the edge of the great ice barrier in the middle of the Antarctic summer.

APPENDIX I.

By letter dated March 5, 1901, Mr. Bernacchi encloses the subjoined additional Tables:—

AURORÆ OBSERVED AT CAPE ADARE.

	Month.	Number of Days.
1899.	March	4
	April	6
	May	12
	June	12
	July	18
	August	15
	September	5
	October	1
	Total	73

APPENDIX II.

HOURS OF BRIGHT SUNSHINE RECORDED BY THE CAMPBELL-STOKES INSTRUMENT.

	Month.	Hours.	
1899.	March	54	
	April	25	
	May	8	
	June	nil	sun below horizon.
	July	nil	
	August	27	
	September	57	
	October	185	
	November	216	
	December	95	
1900.	January	36	
	Total	703	

Time from 6 a.m. to 9 p.m.

LOUIS BERNACCHI.

VI.

WAVE OBSERVING.

BY COMMANDER WILSON-BARKER, R.N.R., F.R.S.E.

A FEW rules on the observation of waves, their height, speed and movement, may not be out of place in this volume. The subject is deeply interesting, and much correct and valuable information may be easily obtained by those who will take the trouble to be accurate in their method of working. The length of a wave is its measurement from hollow to hollow, or from crest to crest; its height is the vertical distance from crest to hollow; a wave's period is the number of seconds it takes to travel a distance equal to its length; and its velocity is the speed of advance of the wave crest (counted in feet) per second. To ensure correct reckoning, two observers should operate:

A, to watch the waves;
B, to write down the time.

Thus, A takes his place in that part of the ship most convenient for his purpose, presumably on the bridge; he fixes on a particular point for observation and sets to work. He first notes the direction and speed of the ship, the direction * and force of the wind, and the direction of the sea. He then tells B to look out, and each time a wave reaches his point of observation, sings out, "Stop!" B promptly writes down the time.

The speed of a wave is ascertained by noting the time it takes to travel the length of the ship. To find the height of a wave above water line, the observer should mount the rigging, or other convenient spot, until high enough to see the horizon over the top of the crest. Thus, if he mount ten feet above the deck (which is ten feet above water line), and can then see a wave crest level with the horizon, the height of that wave is twenty feet. This observation must be taken at a moment when the ship is on an even keel (upright).

Three or four different sets of about thirty observations each

* Best found by observing the curl on the waves.

should be taken at one time, as waves appear to run in series. The more numerous the observations, the more accurate the mean result is likely to be. A little practice will make wave timing easy, except in a cross or confused sea, which complicates matters. If it be desirable to note the rolling of the ship simultaneously with the timing of the waves, a third observer will be required for that purpose, but such a set of observations may very well be taken before or after the others.

In all cases the results obtained can, of course, only be regarded as approximate, but when sufficient care has been taken they are quite near enough for all practical purposes.

VII.

THE AURORA.

BY PROFESSOR ARTHUR SCHUSTER, F.R.S.

FOR an account of the general appearance of the aurora we cannot do better than transcribe Lieutenant Weyprecht's description (Payer's 'New Lands within the Arctic Circle'), as quoted in Mr. Rand Capron's book on the Aurora.

"There in the south, low on the horizon, stands a faint arch of light. It looks as it were the upper limit of a dark segment of a circle; but the stars, which shine through it in undiminished brilliancy, convince us that the darkness of the segment is a delusion produced by contrast. Gradually the arch of light grows in intensity and rises to the zenith. It is perfectly regular; its two ends almost touch the horizon, and advance to the east and west in proportion as the arch rises. No beams are to be discovered in it, but the whole consists of an almost uniform light of a delicious tender colour. It is transparent white with a shade of light green, not unlike the pale green of a young plant which germinates in the dark. The light of the moon appears yellow contrasted with this tender colour, so pleasing to the eye and so indescribable in words, a colour which nature appears to have given only to the Polar Regions by way of compensation. The arch is broad, thrice the breadth, perhaps, of the rainbow, and its distinctly marked edges are strongly defined on the profound darkness of the Arctic heavens. The stars shine through it with undiminished brilliancy. The arch mounts higher and higher. An air of repose seems spread over the whole phenomenon; here and there only a wave of light rolls slowly from one side to the other. It begins to grow clear over the ice; some of its groups are discernible. The arch is still distant from the zenith, a second detaches itself from the dark segment, and this is gradually succeeded by others. All now rise towards the zenith; the first passes beyond it, then sinks slowly towards the Northern horizon, and as it sinks loses its intensity. Arches of light are now stretched over the whole heavens;

seven are apparent at the same time on the sky, though of inferior intensity. The lower they sink towards the North the paler they grow, till at last they utterly fade away. Often they all return over the zenith, and become extinct just as they came.

"It is seldom, however, that an Aurora runs a course so calm and so regular. The typical dark segment, which we see in treatises on the subject, in most cases does not exist. A thin bank of clouds lies on the horizon. The upper edge is illuminated; out of it is developed a band of light, which expands, increases in intensity of colour, and rises to the zenith. The colour is the same as in the arch, but the intensity of the colour is stronger. The colours of the band change in a never-ceasing play, but place and form remain unaltered. The band is broad, and its intense pale green stands out with wonderful beauty on the dark background. Now the band is twisted into many convolutions, but the innermost folds are still to be seen distinctly through the others. Waves of light continually undulate rapidly through its whole extent, sometimes from right to left, sometimes from left to right. Then, again, it rolls itself up in graceful folds. It seems almost as if breezes high in the air played and sported with the broad flaming streamers, the ends of which are lost far off on the horizon. The light grows in intensity, the waves of light follow each other more rapidly, prismatic colours appear on the upper and lower edge of the band, the brilliant white of the centre is enclosed between narrow stripes of red and green. Out of one band have now grown two. The upper continually approaches the zenith, rays begin to shoot forth from it towards a point near the zenith to which the South Pole of the magnetic needle, freely suspended, points.

"The band has nearly reached it, and now begins a brilliant play of rays lasting for a short time, the central point of which is the magnetic Pole—a sign of the intimate connection of the whole phenomenon with the magnetic forces of the earth. Round the magnetic Pole short rays flash and flare on all sides, prismatic colours are discernible on all their edges, longer and shorter rays alternate with each other, waves of light roll round it as a centre. What we see is the auroral corona, and it is almost always seen when a band passes over the magnetic pole. This peculiar phenomenon lasts but a short time. The band now lies on the Northern side of the firmament; gradually it sinks, and pales as it sinks; it returns again to the South to change and play as before. So it goes on for hours: the aurora incessantly changes place, form and intensity. It often entirely disappears for a short time, only to appear again suddenly, without the observers clearly perceiving how it came and where it went; simply, it is there.

"But the band is often seen in a perfectly different form. Frequently it consists of single rays, which, standing close together, point in an almost parallel direction towards the magnetic pole. These become more intensely bright with each successive wave of light; hence each ray appears to flash and dart continually, and their green and red edges dance up and down as the waves of light run through them. Often, again, the rays extend through the whole length of the band, and reach almost up to the magnetic Pole. These are sharply marked, but lighter in colour than the band itself, and in this particular form they are at some distance from each other. Their colour is yellow, and it seems as if thousands of slender threads of gold were stretched across the firmament. A glorious veil of transparent light is spread over the starry heavens; the threads of light with which this veil is woven are distinctly marked on the dark background; its lower border is a broad intensely white band, edged with green and red, which twists and turns in constant motion. A violet-coloured auroral vapour is often seen simultaneously on different parts of the sky.

"Or, again, there has been tempestuous weather, and it is now, let us suppose, passing away. Below, on the ice, the wind has fallen; but the clouds are still driving rapidly across the sky, so that in the upper regions its force is not yet laid. Over the ice it becomes somewhat clear; behind the clouds appears an Aurora amid the darkness of the night. Stars twinkle here and there; through the opening of the clouds we see the dark firmament, and the rays of the aurora chasing one another towards the zenith. The heavy clouds disperse, mist-like masses drive on before the wind. Fragments of the Northern Lights are strewn on every side: it seems as if the storm had torn the aurora bands to tatters, and was driving them hither and thither across the sky. These threads change form and place with incredible rapidity. Here is one! lo, it is gone! Scarcely has it vanished before it appears again in another place. Through these fragments drive the waves of light: one moment they are scarcely visible, in the next they shine with intense brilliancy. But their light is no longer that glorious pale green; it is a dull yellow. It is often difficult to distinguish what is aurora and what is vapour; the illuminated mists as they fly past are scarcely distinguishable from the auroral vapour which comes and goes on every side.

"But, again, another form. Bands of every possible form and intensity have been driving over the heavens. It is now eight o'clock at night, the hour of the greatest intensity of the Northern Lights. For a moment some bundles of rays only are to be seen in the sky.

In the South a faint, scarcely visible band lies close to the horizon. All at once it rises rapidly, and spreads east and west. The waves of light begin to dart and shoot: some rays mount towards the zenith. For a short time it remains stationary, then suddenly springs to life. The waves of light drive violently from east to west, the edges assume a deep red and green colour, and dance up and down. The rays shoot up more rapidly, they become shorter; all rise together and approach nearer and nearer to the magnetic Pole. It looks as if there were a race among the rays, and that each aspired to reach the Pole first. And now the point is reached, and they shoot out on every side, to the North and the South, to the East and the West. Do the rays shoot from above downwards, or from below upwards? Who can distinguish? From the centre issues a sea of flames: is that sea red, white or green? Who can say? It is all three colours at the same moment! The rays reach almost to the horizon: the whole sky is in flames. Nature displays before us such an exhibition of fireworks as transcends the powers of imagination to conceive. Involuntarily we listen: such a spectacle must, we think, be accompanied with sound. But unbroken stillness prevails; not the least sound strikes on the ear. Once more it becomes clear over the ice, and the whole phenomenon has disappeared with the same inconceivable rapidity with which it came, and gloomy night has again stretched her dark veil over everything. This was the aurora of the coming storm—the aurora in its fullest splendour. No pencil can draw it, no colours can paint it, and no words can describe it in all its magnificence."

The chief features of scientific importance at the present moment may be classified as follows:—

1. The arch. Is the vertex of the arch always in the magnetic meridian, and to what extent may it deviate from it? Is the form of the arch always consistent with the theory that it is a horizontal ring suspended in the atmosphere and seen in perspective?

2. What is the relation of the aurora to cloud formations? Is there especially independent evidence of the presence of the crystals in the atmosphere during the manifestations of the aurora? Do the movements of auroral streamers show any evidence of being affected by "wind"?

3. Does the frequency of the aurora show any periodicity depending on the phases of the moon?

4. The spectrum of the aurora.

As regards the position and shape of the arch, the observer should try, whenever a well-defined arch appears, to fix carefully the position of the vertex with reference to the magnetic meridian. The

altitude of the vertex will be more difficult to determine, owing to its variability, but, when possible, the altitude and the azimuth of the points where the arch rests on the horizon should be simultaneously observed. If the observations are always made from the same spot it may be possible to place landmarks so that azimuth and altitude may be quickly determined. The important questions as to the relation of the aurora to cloud formations, and of their periodicity, can only be satisfactorily dealt with if a careful record is kept of every appearance of the aurora.

The observers cannot do better than to follow the guidance of the system of observation adopted by the Austrian Expedition during the international polar observations carried out at Jan Mayen, and published by the Austrian Academy of Science. The appearance of the aurora, following Weyprecht's guidance, is there divided into eight features.

1. *The Arch.*—The inside of the arch is often described as being very dark, and stars are observed in it. Such cases should be recorded.

2. *Bands.*—These make the impression of being portions of arches, changed in form and direction, and often moving about irregularly.

3. *Filaments and Streamers.*—The expression filaments may be taken as the equivalent of the German "Faden," while the German word Strahlen is applied by the Austrian Expedition to what we should call "streamers." Filaments and streamers differ chiefly by their width, which is narrow and uniform in the case of filaments, while streamers are wide and tapering at one end. The direction and motion of these streamers is of importance. When they are parallel and nearly vertical they give the idea of "draperies" or "curtains," and the appearance is sometimes described in this way.

4. *The Corona.*—This appears always near the zenith, and is a very characteristic phenomenon. A circular band is formed round the zenith, either by the apparent contraction of an arch or by symmetrical arrangements of bands, filaments or flames. Streamers or filaments shoot out from the corona towards the horizon.

5. *Auroral Nebulosities.*—These are indistinct nebulous masses, floating about without distinct outline.

6. *Auroral Segments.*—This is described by Weyprecht as "an apparently dark segment of a circle, which is bordered by a low-lying, not varying, luminous arch, and is situated in the magnetic North and South. These segments have not been seen at Jan Mayen.

7. *Auroral Glow.*—A luminous appearance, high up in the sky, the filaments diverging towards the zenith.

8. *Fans and Flames.*—These are luminous appearances to which

various names have been given, according to the objects which their forms simulate. They appear to be collections of streamers arranged so as to give the appearance, sometimes of a feather, or of a fan, or of an irregular bundle of filaments.

The various periodicities of the aurora, some well ascertained but others still very doubtful, form a very interesting field of enquiry. The difficulty of the investigation lies in the separation of true periodicity from a periodic variation of visibility. The aurora, for instance, cannot be observed in full daylight: hence, if records of the presence or absence of the aurora are examined, it is clear that at first sight a diurnal variation would present itself, and the aurora would *seem* to occur more frequently when the sun is below the horizon than when it is above. On second thoughts the observer might be inclined to reject this periodicity and put it down altogether to the difference in visibility. A closer examination, however, will again bring him back to the first view, viz. that he is dealing with a real phenomenon, because there is, even in the hours of the night, a clear difference between the evening and morning hours, the aurora appearing much more frequently before and near midnight than near sunrise. Also, in the long winter night of the arctic region, where differences of visibility are to a great extent excluded, the diurnal periodicity shows itself distinctly.

The annual variation is more difficult to investigate, as observations in the summer months are excluded, and even two months like December and March have such a great difference in the duration of darkness that a comparison becomes very difficult. The only way to prove the annual variation would be to compare the number of auroræ seen in different months during the same hour.

A periodicity depending on the phases of the moon has been made probable, but cannot be said to be proved. Observers should pay special attention to this matter, and carefully note how far the difference in the visibility of the aurora during full and new moon may affect their results.

To arrive at a satisfactory conclusion in these matters it is not only necessary to note down carefully the presence of an aurora, with, as nearly as possible, its time of appearance and disappearance, but also to give, for each time of observation at which no aurora appears, information as to whether the observer is satisfied that the aurora was really absent, or whether, in his judgment, it might have been present, but hidden by clouds or rendered invisible by the strong light of full moon.

The spectrum of the aurora presents some interesting problems,

which, however, no observer can usefully attack without previous experience in spectroscopic matters. An observer who has had such experience will probably know what to do, but attention may be drawn to the extreme importance of obtaining photographic records of the spectrum of the aurora, especially if a satisfactory reference spectrum can be added to the plate. Possibly the solar spectrum (obtained from the sky or moon) may be sufficient, but in case a small induction coil is available a selection of Geissler tubes would prove useful.

The best summary of existing observations connected with auroræ and their connection with other phenomena is contained in relation to 'Les Aurores Polaires,' by A. Argot (Felix Alcan, Paris).

VIII.

ATMOSPHERIC ELECTRICITY:

INSTRUCTIONS FOR THE OBSERVATION OF ATMOSPHERIC ELECTRICITY.

BY LORD KELVIN, G.C.V.O. D.C.L. LL.D. F.R.S.

THE instrument to be used is the portable electrometer described in Sir Wm. Thomson's reprint of 'Papers on Electrostatics and Magnetism,' Sections 368–378.* Full directions for keeping the instrument in order, preparing it for use, and using it to make observations of atmospheric electricity are to be found in Sections 372–376; these are summarised in the following short practical rules:

I. The instrument having been received from the maker with the inner surface of the glass, and all the metallic surfaces within clean and free from dust or fibres, and the pumice dry; to prepare it for use:

(1) Remove from the top the cover carrying the pumice. Drop upon the pumice a small quantity of the prepared sulphuric acid supplied with the instrument, distributing it as well as may be over the whole surface of the stone. There ought not to be so much acid as to show almost any visible appearance of moisture when once it has soaked into the pumice. Replace the cover without delay, and screw it firmly in its proper position, and then leave the instrument for half an hour or an hour, or any longer time that may be convenient, to allow the inner surface of the glass to be well dried through the drying effect of the acidulated pumice on the air within.

(2) Turn the micrometer screw till the reading is 2000. (There are 100 divisions on the circle which turns with the screw on the top outside, and the numbers on the vertical scale inside show full turns of the screw. Thus each division on the vertical scale inside corresponds to 100 divisions on the circle; and 20 on the vertical scale is read "2000.") Introduce the charging rod and give a charge of

* A copy of this book has been sent by the Author for the use of the officer or officers to whom the observations of atmospheric electricity are committed.

negative electricity by means of the small electrophorus which accompanies the instrument. When enough has been given to bring the hair a little below the middle of the space between the black dots, give no more charge; but remove the charging rod and close the aperture immediately. If now the hair is still seen a little below the middle of the space between the black dots, turn the screw head in such a direction as to raise the attracting disc, and so diminish the attraction till the hair is exactly midway between the dots. Watch the instrument for a few minutes, and if the hair is seen to rise, as it generally will (because of the electricity, which has been given, spreading over the inner surface of the glass), turn the micrometer screw in the direction to lower the attracting plate, so as to keep the hair midway between the dots.

(3) The insulation will generally improve for several hours, and sometimes for several days, after the instrument is first charged. The instrument may be considered to be in a satisfactory state if the earth reading does not diminish by more than 30 divisions per 24 hours. If the maker has been fortunate with respect to the quality of the substance of the glass jar, the earth reading may not sink by more than 30 divisions per week, when the pumice is sufficiently moistened with strong and pure sulphuric acid. Recharge with negative electricity occasionally so as to keep the earth reading between 1000 and 2000.

II. To keep the instrument in order. Watch the pumice carefully, looking at it every day. If it begins to look moist, remove the cover, take out the screws holding the lead cup, remove the pumice and dry it on a shovel over a fire. When cool, put prepared sulphuric acid on it, replace it in the instrument, and re-electrify according to No. I.

Never leave the pumice unwatched, in the instrument, for as long as a week. WHEN THE INSTRUMENT IS TO BE OUT OF USE FOR A WEEK OR LONGER, TAKE THE PUMICE OUT OF IT.

III. To use the portable electrometer for observing atmospheric electricity:

(1) The place of observation, if on board ship, must be as far removed from spars and rigging as possible. In a sailing ship or rigged steamer the best position for the electrometer generally is over the weather quarter when under way, or anywhere a few feet above the tafferel when at anchor. On shore or on the ice a position not less than 20 yards from any prominent object (such as a hut or a rock or mass of ice or ship), standing up to any considerable height above the general level, should be chosen. Whether on board ship or in an open boat or on shore or on the ice, the electrometer may be

held by the observer in his left hand while he is making an observation; but a fixed stand, when conveniently to be had, is to be preferred, unless in the case of making observations from an open boat.

(2) To make an observation in ordinary circumstances the observer stands upright and holds or places the electrometer in a position about five feet above the ground (or place on which he stands), so as to bring the hair and two black dots about level with his eye. The umbrella of the principal electrode being *down* to begin with (and so keeping metallic connection between the principal electrode and the metallic case of the instrument), the observer commences by taking an "earth reading."* The steel wire, with a match stuck on its point, being in position on the principal electrode, the match is then lighted, the umbrella lifted, and the micrometer screw turned so as to keep the hair in the middle between the black dots. After the umbrella has been up and the match lighted for 20 seconds or half a minute, a reading may be taken and recorded, called an "air reading." A single such reading constitutes a valuable observation. But a series of readings taken at intervals of a quarter of a minute, or half a minute, or at moments of maximum or minimum electrification during the course of two or three minutes, the match burning all the time, is preferable. In conclusion, remove the match if it is not all burned away, lower the umbrella home, and take an earth reading.

(3) The electric potential of the air at the point of the burning match is found by subtracting the earth reading from the air reading at any instant. When the air reading is less than the earth reading the air potential is negative, and is to be recorded as the difference between the earth reading and the air reading, with the sign – prefixed. The earth reading may be generally taken as the mean between the initial and final earth readings. But the actual earth readings and air readings ought all to be recorded carefully, and the full record kept.

(4) Note and record the wind at the time of each observation, also the character of the weather.

IV. Observations to be made:

(1) At the commencement of the Expedition, in the course of the Southward voyage, observations of atmospheric electricity ought to be taken regularly three or four times a day; also occasionally during the night, to give the observer some practice in the use of a lantern for reading the divisions on the circle and of the vertical scale.

(2) When stationary in winter quarters, observations should be

* 'Electrostatics and Magnetism,' § 375.

made three times a day at intervals of six hours; for example, at 8 a.m., 2 p.m., and 8 p.m., or at 7.30 a.m., 1.30 p.m., and 7.30 p.m. Whatever times are most convenient may be chosen, provided they be separated by intervals of six hours.

(3) It is very desirable that hourly observations should be made, if only for a few days, in winter and in summer. If possible, arrangements to do so, at least for six consecutive days in winter and for six consecutive days in summer, should be made. The results will be very interesting as showing whether there is a diurnal or semi-diurnal period in either the Antarctic winter or summer.

(4) Make occasionally special observations when there is anything peculiar in the weather, especially with reference to wind.

V. Special precautions:

(1) In the Antarctic climate more care may be necessary than in ordinary climates as to earth connections. Therefore put a piece of metal on the stand on which the electrometer is placed during an observation on board ship, and keep this in metallic communication with the ship's coppers. If the electrometer is held in the hand with a glove on, a piece of the fine wire supplied with the instrument ought to be tied round the brass projection which carries the lens, or otherwise attached to the outer case of the electrometer, and by this wire sufficient connection maintained with the earth during an observation. The connection will probably be sufficient if a short length of the wire is laid on the ice and the observer stands on it. Enough, however, is not yet known as to electric conductivity of ice: and to make sure, it *may* be necessary to have a wire or chain let down to the water through a hole in the ice, and metallic connection kept up by a fine wire between this and the electrometer case during an observation.

(2) The observer's cap (particularly if of fur) and his woollen clothing, and even his hair if not completely covered by his cap, will be apt in the Antarctic climate to become electrified by the slightest friction, and so to give false results when the object to be observed is atmospheric electricity. A tin foil cover for cap and arms, kept in metallic communication by a fine wire with the hand or hands applied to the case of the electrometer or to the micrometer screw head, should therefore be used by the observer (and assistant, if he has an assistant to carry lantern, or for any other purpose), unless he has made sure that there is no sensible disturbance from those causes, without the precaution. Tin foil for this purpose is supplied with the instrument.

VI. Instruments, stores, and appliances for observation of atmospheric electricity sent with the Expedition:

(1) Two portable electrometers, each with one steel wire for carrying match, one charging rod, and one electrophorus for charging the jar.

(2) Six spare steel wires for carrying the match (three to go with each instrument).

(3) Supply of matches ready made. (The slower the match burns, the better. If those supplied burn too fast, steep them in water and dry them again.)

(4) White blotting paper and nitrate of lead to make more matches when wanted. (Moisten the paper with weak solution of nitrate of lead, and roll into matches with thin paste made with a very little nitrate of lead in the water.)

(5) Six spare pumices (three for each electrometer); indiarubber bands to secure pumice in lead case.

(6) Eight small stoppered bottles of prepared sulphuric acid (four for each electrometer).

(7) Tin foil and fine wire.

IX.

CHEMICAL AND PHYSICAL NOTES.

By J. Y. Buchanan, F.R.S.

It is unnecessary to frame instructions to the chemist and physicist with regard to the performance of routine operations. He must be fully instructed and practised in these matters before he leaves. Still less is it necessary to frame instructions for carrying out delicate operations such as the determination of the amount of carbonic acid, and of the permanent gases present in the sea-water, because these operations can only be carried out, in the way that would justify the expenditure of time, by an expert who had previously provided himself with all the apparatus and appliances which are necessary.

But there is another class of observations which it is very desirable to make. They are not routine observations; they may rather be termed observations by the way. Elaborate provision of instruments is not necessary. What is most important is to have a definite idea of the kind of observations that are wanted, and of the way to make them.

The following notes have reference to this class of work, which is perhaps the most fascinating, and may be the most fruitful that can be engaged in. They are for a large part reprinted from two papers, one of which * was originally drawn up with a view to an Antarctic Expedition, and was read at the Dover Meeting of the British Association in 1899; the other† is a paper which was read before the Royal Society in May 1894, and consists of the daily record of "observations by the way," such as it is most important that we should have from the Antarctic Land and Ice. The paper is reproduced almost in its entirety, because its principal usefulness consists in small matters and minute details which would be eliminated in condensation.

* 'On the Physical and Chemical Work of an Antarctic Expedition,' by J. Y. Buchanan, F.R.S. *Geographical Journal*, November, 1899.

† 'On Rapid Variations of Atmospheric Temperature, especially during *Föhn*, and the methods of observing them,' by J. Y. Buchanan, F.R.S. *Proc. R.S.*, vol. lvi. p. 108.

Low Oceanic Temperatures: Ice at Sea and on Land, &c.*

One of the striking features of the ocean discovered by the *Challenger* expedition, was the extensive area of very cold water which occupies the bottom of the sea from the east coast of South America to the ridge which runs north and south in the meridian of the island of Ascension. Here the bottom temperature was found to be 32°·5 Fahr. The existence of this exceptionally cold bottom water was discovered on the outward voyage in soundings near the Brazilian coast, so that the expedition was prepared to take up the study of it on the way home. This was done very thoroughly on a line from the mouth of the river Plate along the parallel of 35° to the meridian of Ascension. The depth of the water varied from 1900 to 2900 fathoms, and the distribution of temperature in the water was, roughly, a warm surface layer of perhaps 100 to 200 fathoms, then a thick layer of water of temperature about 36° Fahr. down to 1600 fathoms near the coast, and to 2200 fathoms or thereabouts at sea. Here was a steep temperature-gradient falling away rapidly from 35° to 33° Fahr., and more slowly to 32°·5 Fahr. The occurrence of the steep gradient shows a renewal of the water, and therefore a current. The observations of the *Valdivia* show a similar distribution in lat. 60° to 63° S., with this difference—that the surface layer is colder than the intermediate one, which is itself colder than the former intermediate, being about 34° Fahr. The bottom layer has as low a temperature as 31°·5 Fahr. Unfortunately, there are not enough determinations of the temperature of the deeper layers to indicate the gradient which separates the cold bottom water from the comparatively warm intermediate water. The recommendation, therefore, which the writer would make is, that in these regions temperature observations in the deeper layers should not be spared, and where there is water of exceptional coldness at the bottom, the position and steepness of the gradient which separates it from the overlying water should be accurately determined. Further, as the whole range of temperature to be dealt with in Antarctic water is at the most from 28° to 35° or 36° Fahr., and therefore small differences of temperature are relatively of great importance, it is well to have the thermometers constructed specially for this work, the scale containing few degrees, but these wide apart. In the survey of the Gulf of Guinea in the *Buccaneer*, the writer had such thermometers, and he regularly sounded with one thermometer at the end of the wire, and another usually 250 fathoms above it.

* 'On the Physical and Chemical Work of an Antarctic Expedition,' by J. Y. Buchanan, F.R.S. *Geographical Journal* for November 1899.

It is also of great importance to ascertain the density of this exceptionally cold bottom water. Near the coast of South America it was found in the *Challenger* to be very high, and this was confirmed by an observation of the *Gazelle* in the same locality. It is this density at constant temperature which decides whether a water can carry its surface temperature down to great depths, or whether it shall remain at the surface, and it is the annual range of temperature of such water which gives it its penetrating power. This was clearly set forth in a paper sent home during the first year of the voyage of the *Challenger*, and published in the *Proceedings of the Royal Society*.* The highest surface densities are found in the North Atlantic, in the Trade-wind regions, and there the surface water has a higher density than any layer below it; consequently, when it is cooled in winter to the same temperature as the water immediately below it, it sinks through it, and in this way a high temperature is disseminated through the whole thickness of the water of the North Atlantic. In the eastern part of this ocean, the density and temperature of the bottom waters are sensibly increased by the "brining down" of the Mediterranean.

The common feature of Antarctic water found by all expeditions is the thick warm layer lying between a cold layer at the surface and another cold layer at the bottom. It is very important to trace these two cold layers Southwards, until they join and the warm intermediate layer has disappeared. Every particular connected with this will be of interest.

Freezing Temperature of average Sea Water.—Sir James Ross, in his description of his voyage, frequently refers to 39° Fahr. as the temperature of maximum density of all waters, and draws curious conclusions. Now it was well known before the date of his voyage that average sea-water continues to contract to a much lower temperature than 39°. Indeed, its temperature of maximum density is below that of its freezing-point, which may be put at 29° Fahr. A similar mistake is often made at the present day by geographical writers. Although everybody knows and recognises that sea-water freezes at a temperature below that of fresh water, and that this temperature is the lower the greater the quantity of salt contained in the sea-water, it is to some extent not known and to a great extent not recognised that pure ice, which when left to itself melts at 32° Fahr., begins to melt in salt water at exactly the same temperature as that at which the same water begins to freeze. A piece of pure lake-ice immersed in average sea-water

* *Proc. R.S.* (1875), vol. clvii. p. 123.

reduces its own temperature and that of the sea-water in its immediate neighbourhood to a temperature of roughly 29° Fahr., which varies with the concentration of the resultant brine formed by the mixture of the sea-water with the pure water formed by the melting of the ice. An iceberg consists of pure land-ice, and if it is of sufficient thickness to reach the layer of warm intermediate water, its lower surface must be always melting at a temperature of about 29° Fahr., and this temperature must in time be communicated to the body of the ice, if it did not have it before. But it must necessarily be at about this temperature, because it separates from the parent land ice after it has been pushed into the sea. If it had a temperature below 29° Fahr., it would freeze the sea-water round it until it had got rid of its excessive cold; and if it had a temperature above 29° Fahr., the sea-water round it would melt its ice until it had got rid of its excessive heat. The representative freezing temperature of sea-water is taken as 29° Fahr., but it varies with the salinity. In this respect sea-water was found to agree closely with a solution of chloride of sodium containing the same percentage of chlorine. The subject was carefully investigated during the winter 1886–87, and the results were communicated to the Royal Society of Edinburgh, in a paper which was read on March 21, 1887.* The rule regulating the appearance or disappearance of ice in a solution of chloride of sodium is very simple. The number expressing the percentage by weight of chlorine in the solution expresses on Celsius' scale the depression of the freezing-point of the solution below that of distilled water, and by consequence the temperature at which pure ice begins to melt in the same solution. Thus the freezing-point of a solution of chloride of sodium, containing 1 per cent. of chlorine, is $-1^\circ{\cdot}0$ C.; if it contains 1·75 per cent. chlorine, its freezing point is $-1^\circ{\cdot}75$ C.; and so on for concentrations not exceeding that of the saltest ocean water. Sea-water, the solid contents of which consist chiefly of chlorides, follows this rule approximately, but not exactly. The following table, from p. 133 of the memoir, is derived from twenty-five determinations made with the greatest care in sea-waters of different degrees of concentration and freezing at temperatures between $-0^\circ{\cdot}5$ C. and $-2^\circ{\cdot}22$ C.

Freezing temperature	$-2^\circ{\cdot}0$ C.	$-1^\circ{\cdot}5$ C.	$-1^\circ{\cdot}0$ C.	$-0^\circ{\cdot}5$ C.
Per cent. by weight of chlorine	1·940	1·445	0·963	0·475
Difference	0·060	0·055	0·037	0·025

From this we have the following approximate rule: *The number expressing on Celsius' scale the depression of the freezing-point of a*

* 'On Ice and Brines,' by J. Y. Buchanan (1887). *Proc. R.S.E.*, vol. xiv. p. 129; also *Nature* (1887), vol. xxxv. pp. 516, 608, and vol. xxxvi. p. 9.

sea-water below that of distilled water is found by adding 0·04 to the number expressing the percentage by weight of chlorine in the same water. From these few remarks, it will be seen that the mutual interaction between ice, salt, and water must be taken into account in interpreting the results of the sea-temperatures of the Antarctic.

Sea Ice as met with in Polar Seas.—The above law refers to ocean waters which contain not more than 4 per cent. of dissolved matter. In the course of a Polar winter the sea freezes to a thickness of 8 or 10 feet, and in proportion as the ice gets thicker, the actions and reactions between ice and brine and salt and water become more complex, and the law of freezing is no longer so simple as that stated above.

Sea ice, as it occurs in the Arctic ocean, has been described in great detail by Weyprecht, in a work * which should be included in the library of every Antarctic expedition. The *Tegetthoff*, which was Weyprecht's ship, was beset in the pack in lat. 76° 18′ N., long. 61° 17′ E., on August 13, 1872. Twenty-one months later she was still a prisoner in the pack, and had to be abandoned. During all these months there was no lack of time or opportunity to study sea-ice in all its forms and moods, and every line of Weyprecht's book is of interest to the voyager in icy seas. The matter is treated quite objectively. First the different forms which the ice assumes and their origin are dealt with; then ice-pressure, of which the *Tegetthoff* had sufficient experience, and the nature of sea-ice in winter and in summer, are described. In winter we have the formation of the ice and its transformations under the combined influence of cold and varying pressure; in summer, unfortunately for the *Tegetthoff*, there was no opportunity of studying the disappearance of the ice, but its transformations under the influence of melting and varying pressure are described. After these detailed studies, we have a description of the motions of the ice and of the water as observed in North Polar regions, and speculations as to what may be expected to take place in regions not then visited.

For the chemist and the physicist the following extracts, which describe the freezing of sea-water under severe cold, are of special interest:

Page 55.—The author is here describing the ice which surrounded the *Tegetthoff* during the winter. Referring to the openings which occurred in it from time to time and without apparent reason, he says:—

* 'Die Metamorphosen des Polareises,' von Karl Weyprecht. Wien, Moritz Perles, 1879.

"If the cold is very intense, then such quantities of vapour rise from the water, so soon as it comes in contact with the air, that it looks as if a veil had been spread over the surface of the water. The masses of vapour which rise are so dense that it looks as if the opening of the ice were filled with hot water.

"This does not, however, last long. The evaporation of the water which furnishes the vapour removes heat from the water and assists the cold of the air in producing a covering of young ice. In a very short time the surface of the water begins to get thick, and threads like a spider's web run out from the edge of the old ice towards the middle. The covering which at first was thin and pasty acquires consistence and thickness; the production of vapour diminishes, and soon ceases.

"At this stage the salt-water ice is a pasty mass, which follows every surface movement of the water on which it floats. With increasing thickness this ice-mass acquires greater consistence and becomes tougher, but even with very intense cold it does not become sufficiently strong to bear the weight of a man with safety until after thirty to thirty-six hours. With a temperature of −40° C. the new ice, even after twelve hours, is still so soft that, in spite of its thickness, a stick can be easily thrust through it. On December 13, 1872, the ice had in sixty hours attained a thickness of 20 centimetres, the temperature being −35° C. But even with this thickness it is still in no way brittle, but is so pasty that it gives way under the weight of a man, without breaking. It gives the impression that one is walking on well-stretched leather, and it keeps this leathery character for a long time. Even after fourteen days, when its thickness is over half a metre, it does not break when exposed to moderate pressure, but crumples up with undulating folds. An expanse of young ice in this state looks as if the water, when in motion, had been surprised by the cold and every wave had suddenly been turned into ice.

"This persistent viscosity is caused by the large amount of salt which remains in the upper layers of the ice frozen by intense cold, and of the moisture which it attracts. In the formation of each ice-crystal, the salt is completely excluded. When the ice formation takes place very rapidly, under the influence of very low temperature, a large number of ice-crystals are formed in a very short time, and much of the salter brine remains entangled in them. Consequently the ice covering which first forms consists of loose ice-crystals, mixed with the brine from which they have been formed. As the cold continues, more ice is formed out of the brine, and the

residual brine becomes more concentrated: but, however great the cold, the surface layers of sea-water ice never acquire the hardness or present the appearance of fresh-water ice. When the ice has acquired a certain thickness, the formation of ice at the lower surface takes place slowly, and the excluded brine disseminates itself at once in the water. The ice, so formed, is much freer from salt than that which was first formed on the water surface. The thicker the young ice becomes, the less influence does the comparatively warm sea-water have on the upper layers of the ice, and the lower does the temperature of the ice and the entangled brine fall.

"But as the brine is always in contact with ice, it is always at its freezing-point, which continually falls as the concentration of the brine increases. By this continual freezing process of brine, which is always getting more and more saturated, the liquid residue approaches more and more the point where it can sustain the greatest cold without freezing. On the surface there remains a very concentrated brine which keeps the ice moist day after day, and which gives it its pastiness. On walking over such a surface, so long as no fresh snow has fallen on it, one is astonished to find that every step one takes remains impressed on the white surface, and it is difficult, especially for a new-comer, to understand how what he takes for snow can be in a state of thaw at a temperature of $-40°$ C., and even lower. The moisture which collects in the foot-prints, is however, not water but a very concentrated saline solution, principally chloride of calcium, which in the course of time is absorbed into the ice.

"From the above description of the process of formation of sea-water ice, it is evident that when such ice is melted the saltness of the water produced will vary according as the ice has been taken from the surface layers or from lower down.

"The following determinations were made. The water formed by melting the white surface-ice which had taken thirty-six hours to form under a cold of $-33°\cdot5$ C., has a specific gravity of $1\cdot087$; and water from ice which had taken sixty hours to form under a cold of $-33°$ C., had a specific gravity of $1\cdot076$, both measured at $+6°\cdot2$ C. These measurements correspond to a salinity of $11\cdot8$ and $10\cdot0$ per cent. respectively. This ice was really the efflorescent surface skin.

"The specific gravity of the water produced by melting the uppermost 5 centimetres of the above ice along with the white surface skin was $1\cdot017$ at $+19°\cdot7$, that of the middle 9 centimetres was $1\cdot009$ at $+11°\cdot4$ C., and that of the lowest 5 centimetres was $1\cdot008$

at $+16^{\circ}\cdot 8$ C. These specific gravities correspond to salinities of 2·5, 1·3 and 1·2 per cent. respectively. The average specific gravity of the sea-water is 1·025."

Weyprecht assumed that the ice formed by freezing sea-water was pure ice, and that its saltness was derived from brine mechanically adhering to it, from which it was impossible to free it. There was no experimental evidence to prove this. Others thought that as the ice formed by freezing salt water has a different melting-point from fresh-water ice, and it is impossible by melting it to produce water free from salt, that the salt is an essential constituent of the ice. Experiments made by the writer * in the Antarctic area during the cruise of the *Challenger*, supported the latter view, and he held it until subsequent experiments, † which he made some twelve years later, enabled him to supply direct experimental evidence that the contrary is the case, that the ice-crystals are indeed pure ice, and that their saltness is due only to adhering brine from which it is impossible to free them.

Demonstration that the Ice produced by Freezing Sea-water and similar Solutions is pure Ice.—The principle guiding the research was, that if the ice, which forms when sea-water or saline solutions of similar concentration are partially frozen is pure ice, then pure ice of independent origin such as snow, must, when mixed with the sea-water or saline solution, melt at the same temperature as the ice which is formed by freezing the solution, when the concentration is the same. Sea-water and various saline solutions were experimented with on these lines, and the following was the scheme of experiment:—

The solution of a salt, for instance, chloride of sodium, was gradually cooled in a freezing mixture, and the temperature watched as more and more crystals separated out; at suitable intervals the temperature was accurately noted, and simultaneously a sample of the brine was taken; in this way a series of freezing temperatures t_1, t_2, t_3, etc., was obtained, and after analysis of the samples a corresponding series of salinities s_1, s_2, s_3, etc., was obtained. When the lowest temperature, say t_5, was obtained, the salinity was s_5; then the vessel containing the solution was removed from the freezing mixture, and it was exposed to the heat of the air of the laboratory. The temperature of the mixture was observed to rise slowly, and when it arrived again at t_4, t_3, t_2 and t_1 respectively, samples of the brine were again taken and analysed. The resulting salinities s_4, s_3, s_2,

* 'On Sea-water Ice.' *Proc. R.S.* (1874), vol. xxii. p. 431.

† 'On Ice and Brines, by J. Y. Buchanan (1887). *Proc. R.S.E.*, vol. xiv. p. 129; also *Nature*, vol. xxxv. pp. 516, 608, and vol. xxxvi. p. 9.

s_1, were found to be identical with those observed at the same temperature during cooling.

Another solution of the same salt was now made, and of strength represented by salinity s_5. It was cooled down to close on t_5, and then snow was mixed with it. The vessel having been removed from the cooling bath was exposed to the heat of the laboratory, and the thermometer carefully observed as the temperature rose. When the temperature was exactly t_4, t_3, t_2, t_1, samples of brine were taken and analysed, and the resulting salinities s_4, s_3, s_2, s_1, were found to be identical with those observed in the two previous experiments.

It was thus shown that when a saline solution of concentration comparable with sea-water is gradually frozen, certain crystals which we call ice-crystals separate out, and during the process the temperature of the mixture gradually falls while its concentration increases. When the mixture of brine and ice-crystals is warmed the ice-crystals gradually melt, the temperature rises and the concentration diminishes; but when in the process of cooling and freezing the temperature has fallen to a certain point, say t, and the salinity is s, it was found that when the process was reversed and the same temperature t was reached during the process of warming and melting, the solution was found to have the salinity s. Therefore the substance, which forms the ice-crystals which separate out at a temperature t during cooling, melts again at the same temperature and concentration during warming. When the same solution, having the highest concentration which was used in the previous experiments, was cooled down and mixed with snow and then gradually warmed, it was found that the snow melted exactly as the ice-crystals formed in the solution itself had done, and at exactly the same temperature for the same salinity. But it is only a question of whether the salt is in the ice or in the brine. There is no salt in snow, and it behaves in a saline solution in exactly the same way as the crystals formed by freezing that solution; therefore the crystals formed by freezing the saline solution must be equally free from salt, and *it has thus been proved that the crystals formed in freezing saline solutions of moderate concentration are pure ice, and that the salt from which they cannot be freed does belong to the adhering brine.*

Analogy between Snow and Sea Ice.—Snow is the result of the crystallisation of water-vapour dissolved in a gaseous mixture of nitrogen and oxygen. The freezing-point of this gaseous mixture is commonly called the "dew-point" of the air. The freezing of a saline solution is analogous. It is a homogeneous liquid, and the

water is as much dissolved in the salt as the salt is in the water. When the solution is sufficiently cooled, ice separates in crystals from the liquid salt just as it did from the gaseous air, and *the freezing-point of a solution is in reality a dew-point.* The snow derived from these different sources has identical properties; and when real snow of atmospheric origin is mixed with a saline solution, it is as impossible to free it from salt and to get it to melt at 0° C. as it is to do so with the crystals formed by freezing a saline solution.

This matter has been dealt with at some length, not only because it is of importance for the Antarctic explorer, but because it is a matter of the highest importance in chemistry. The whole of that great branch of physical chemistry, which has the distinctive title of cryoscopy, depends on the fact that a saline solution, in freezing, yields pure ice; yet, in treatises on the subject, no adequate proof of this fundamental fact is offered.

Cryohydrates.—When a saline solution has been exposed to continued freezing, it finally acquires a concentration at which any further removal of water in the form of ice causes the precipitation of salt, because at the temperature attained the solution is saturated with the salt. If the cooling is continued the temperature remains constant, while ice and crystals of the salt separate out *pari passu*, and finally the whole solution may solidify to a porcelain-like mass, which has been called the cryohydrate of the particular salt. If warmed it will melt again at a constant temperature until all the salt has been dissolved, when the temperature will begin to rise. The case is quite analogous to the boiling mixtures * of constant temperature produced by blowing steam through salt, the temperature remains quite constant at that of the boiling saturated solution until nearly all the salt is dissolved, after which the temperature falls in proportion as the solution is diluted by the condensation of steam.

The temperature at which the cryohydrate forms has been called the cryohydric temperature. At this temperature crystals of ice and of the salt remain side by side without melting each other, and they behave with the same indifference to each other at lower temperatures. At temperatures above the cryohydric point they cannot be brought together without melting, when they produce the cryohydric temperature. The cryohydric temperatures of different salts differ. From the observations of Weyprecht, Nordenskjöld, and others, we learn that even at a temperature of −40° C. there is liquid brine in the surface layers of the sea-ice; so that the cryohydric point

* 'On Steam and Brines,' by J. Y. Buchanan, F.R.S. *Trans. R.S.E.* (1899), vol. xxxix. p. 529.

of some of the salts in sea-water must be lower than this temperature. *The temperature of this mixture of ice and brine must be the freezing temperature of the brine and the melting temperature of ice in the brine.*

It has been said that above the cryohydric temperature crystals of the salt and of ice cannot be brought together without liquefaction. When air is saturated with moisture at temperatures below 0° C. the moisture is deposited as rime, which is ice. If the surface on which it is deposited is a soluble salt, and if the temperature is above the cryohydric temperature of the salt, liquefaction will take place at the point of deposit. Hence it follows that *every salt is deliquescent at temperatures between* 0° C. *and its cryohydric temperature.*

Numerical data regarding the freezing-points of saline solutions are to be found in collections of physical tables such as those published by the Smithsonian Institution.

The following table gives the freezing-points of saturated solutions of a number of salts, as recently determined with the greatest care by L. C. de Coppet,* who was the first to prove and to clearly enunciate the relation which exists between the molecular weight of a salt and the freezing-point of its aqueous solution.

TABLE I.

Salt dissolved.		Amount of Salt dissolved in 100 grms. water.	Freezing Temperature of Solution.
		grms.	°C.
Chloride of potassium	KCl	24·6	−11·16
Chloride of sodium	$NaCl$	29·6	−21·85
Chloride of ammonium	NH_4Cl	22·9	−15·8
Nitrate of potassium	KNO_3	10·7	− 2·85
Nitrate of sodium	$NaNO_3$	58·5	−18·5
Nitrate of ammonium	NH_4NO_3	70·0	−17·35
Nitrate of barium	$Ba(NO_3)_2$	4·5	− 0·7
Nitrate of strontium	$Sr(NO_3)_2$	32·4	− 5·75
Nitrate of lead	$Pb(NO_3)_2$	35·2	− 2·7

The meaning of this table is that if, for example, we take 29·6 grms. of common salt (NaCl) and dissolve it in 100 grms. of water, which will take some little time, and we then expose it to an Antarctic temperature such as − 25° C. or − 30° C., the temperature of the solution will fall until it reaches − 21°·85 C., when it will

* *Zeits. f. Phys. Chem.*, vol. xxii. p. 239.

remain stationary while crystals form in the solution. This crystallisation will proceed until the solution has become a white solid enamel-like mass. When it has completely solidified, its temperature will begin to fall again, and will continue to fall until it has reached the temperature of the air, $-25°$ C. or $-30°$ C., as the case may be. The white enamel-like mass is what was called by Guthrie the cryohydrate of chloride of sodium. Although it is no longer believed to be a definite hydrate in the chemical sense of the term, still it is a mixture of NaCl and H_2O in a definite and constant proportion with a constant melting-point, and simulates a chemical compound so successfully that it is well entitled to retain its name of cryohydrate, all the more as it is convenient to have a special name to designate these mixtures. The cryohydrate of chloride of sodium is an intimate mixture of 29·6 grms. of chloride of sodium with 100 grms. of ice. It melts at the constant temperature $-21°·85$ C., and when melted it will, if cooled, solidify again at the same temperature. Below this temperature chloride of sodium and ice are indifferent to each other; above this temperature they melt each other, and between this temperature and 0° C. chloride of sodium is a deliquescent salt.

Again, we see from de Coppet's table that the cryohydrate of chloride of ammonium (NH_4Cl) consists of 22·9 grms. of the salt and 100 grms. of ice, and this mixture can exist either in the liquid or the solid state at $-15°·8$ C. In the case of chloride of sodium it was indicated that by making a solution saturated at ordinary temperatures ($+15°$ C.) we obtained a solution of the concentration of the cryohydrate, which is a solution saturated at the cryohydric temperature ($-21·85°$ C.). It is a remarkable property of common salt that its solubility in water is almost entirely unaffected by change of temperature. The law holds almost universally that salts are more soluble in warm than in cold water. This is the case with chloride of ammonium. At a barometric pressure of 742 mm., when steam is blown through the salt it forms a boiling mixture of salt and saturated solution having the constant temperature of 113°·8 C., the temperature of boiling distilled water under the same pressure being 99°·33 C. This boiling saturated solution contains 78·7 grms. of chloride of ammonium to 100 grms. of water, and on cooling to the ordinary temperature of 15° C. the amount of the salt remaining in solution is only 35·7 grms. to 100 grms. of water, the difference, 43 grms., has separated out as crystals. If the solution, saturated at $+15°$ C. and containing 35·7 grms. of NH_4Cl to 100 grms. of H_2O, be now exposed to a temperature of $-15°·8$ C., its temperature will

fall gradually, until $-15°\cdot8$ C. is reached. During the process of cooling a large amount of the chloride of ammonium crystallises out. It is well known—and the fact can be verified in a moment by making the experiment—that when crystals of chloride of ammonium are mixed with water of ordinary temperature, cold is produced. The cold experienced is the measure of the heat absorbed in the liquefaction of the salt by solution. When the process is reversed and the salt is deposited from the solution this heat is restored, and it is appropriated in the first instance by the solution which is cooling and crystallising, and *pro tanto* it diminishes the rate of cooling and of crystallising. At $-15°\cdot8$ C. the saturated solution of chloride of ammonium contains 22·9 grms. of the salt to 100 grms. of water, so that 12·8 grms. of the salt have crystallised out. Had the solution been originally made to contain only 22·9 grms. of chloride of ammonium to 100 grms. of water at $+15°$ C., and it had then been exposed to the low temperature of $-15°\cdot8$ C., the time in which the solution would have fallen to this temperature would have been much shorter, but the final result would have been the same—we should have an aqueous solution of chloride of ammonium of the cryohydric concentration and at the cryohydric temperature. If this solution were then exposed to a lower temperature, say $-20°$ C., it would lose heat, but its temperature would remain constant at $-15°\cdot8$ C., and the equivalent of the heat removed would be apparent in the ice and salt which would separate out *pari passu* so long as heat was being removed and there remained anything liquid from which to remove it. So soon as the liquid has disappeared and the mass has become solid throughout, the further removal of heat is represented by a fall of temperature of the solid mass; the temperature will fall in time to $-20°$ C., and to any lower temperature to which the solid may be exposed. If it is then warmed by being placed, for instance, in a room having a temperature of $+15°$ C., its temperature will first rise to $-15°\cdot8$ C., at which point it will remain stationary while the mass liquefies. When the mass is all liquid the temperature of the liquid will rise rapidly until it finally assumes that of the room.

We see, then, that at temperatures below $-15°\cdot8$ C. chloride of ammonium and ice are indifferent to each other; above this temperature they melt each other, and at temperatures between 0° C. and $-15°\cdot8$ C. chloride of ammonium is a deliquescent salt.

It might be thought that, as the cryohydric temperature of chloride of sodium is $-21°\cdot85$ C. and that of chloride of ammonium is $-15°\cdot8$ C., the cryohydric temperature of a mixture of them in

equal proportions would be somewhere near the middle, or about $-18°·8$ C. But this is not so. The cryohydric temperature of a mixture of the two salts lies below that of either of the salts; and the same is the case even with the mixtures of the chlorides of sodium and of potassium, the cryohydric temperatures of which are so far apart.

The following rough observations (Table II.) were made in the Engadine on September 20, 1897, when a heavy snowfall occurred.

TABLE II.

Snow Weight.	Salt *a*.		Salt *b*.		Cryohydric Temperature.
	Formula.	Weight.	Formula.	Weight.	
grms.		grms.		grms.	°C.
20	$NaCl$	32	..	..	−21·0
32	KCl	38	..	..	−11·0
34	NH_4Cl	22	..	..	−15·8
36	$NaCl$	11·7	KCl	14·9	−23·0
42	$NaCl$	11·7	NH_4Cl	10·7	−24·8
..	$BaCl_2,2H_2O$	25	..	..	− 7·9
48	$Ba(NO_3)_2$	27	..	..	− 1·0
73	$BaCl_2,2H_2O$	12·2	$Ba(NO_3)_2$	13·07	− 8·6

The temperatures were all observed with the same thermometer and no correction has been applied. The temperature marked $-0°·3$ C. in melting snow, which makes the determined cryohydric temperature of nitrate of barium agree with that found by de Coppet, namely $-0°·7$ C. The thermometer was one of ordinary German manufacture divided into whole degrees. The observations illustrate the fact that the cryohydric temperature of a mixture of two salts is lower than that of the salt which separately has the lower cryohydric temperature of the two. The mixtures experimented on were of equal molecular proportions, in fine powder, intimately mixed with *dry* powdery snow. Perhaps the most remarkable mixture in the table is that of the chloride and nitrate of barium: the cryohydric temperature of the mixture is nearly the sum of the separate cryohydric temperatures. In almost every case where accurate observations have been made, it has been found that the melting temperature of a mixture is lower than that of the most fusible of its components. The frequency of this observation has justified its enunciation as a law, and the recognition and elaboration of this law have done much for the advancement of physical

chemistry. This is not the place to enlarge further on it in its general aspect, but in its particular application to the cryohydric and to the freezing temperatures of solutions of salts and of mixtures of salts, it is of great interest to the scientific members of an Arctic or Antarctic expedition. In recent years workers in physical chemistry have mainly limited themselves to the study of very dilute solutions, and the behaviour of concentrated and saturated solutions when exposed to great cold has received comparatively little attention. Consequently the chemist and physicist of the Expedition has a comparatively unoccupied field before him, and he is free to choose the simplest problems.

In our country the opportunities for the exact study of freezing mixtures are rare, because it seldom snows at all, and when it does, the snow is flaky and at or about its melting-point. Crystalline powdery snow, which has never experienced its melting temperature, is a rarity even on our mountains. This is the only form in which ice should be used for freezing or cryohydric mixtures, when these are to be studied exactly. When a freezing mixture is made with salt and ordinary moist snow, the salt forms little local freezing mixtures where it comes into actual contact with a snow-crystal, and the cold produced freezes the moisture adhering to contiguous snow-crystals, with the result that an altogether impracticable and heterogeneous mass of lumps of ice and masses of salt is formed. In the Antarctic regions cold powdery snow will be common enough, and exact experiments on the temperature and concentration of the freezing mixtures which it makes with different salts, and especially with definite mixtures of salts, will be easy, and cannot fail to be interesting.

The salts must be pure, dry, and in fine powder. When mixtures are used they should be in simple molecular proportions, as for instance, $NaCl + NH_4Cl$, $NaCl + 2NH_4Cl$, $3NaCl + 2NH_4Cl$, and so on. The weighed quantities of the two salts must be thoroughly mixed in a mortar before they are brought together with the snow. The experimenter must feel assured that there is no risk of his freezing mixture consisting of an indefinite association of local freezing mixtures, of, for instance, snow and NaCl and of snow and NH_4Cl, but that it is certainly a homogeneous mixture, every element of which consists of three bodies.

The dry snow has necessarily a low temperature. The salt, or mixture of salts, when finely pulverised and intimately mixed, should be cooled in a stoppered bottle to a temperature below 0° C. When the cold dry salt is mixed with the cold dry snow, and the tempera-

ture, although low, is still above the cryohydric temperature of the mixture, and the temperature of the air when the mixture is made is also above the cryohydric temperature, the temperature of the mixture falls smartly to and stops abruptly at the cryohydric temperature. Even when exposed to the ordinary temperature of an inhabited room, such a mixture, if prepared with any care, will maintain a perfectly constant temperature for a length of time depending on the mass of the mixture made. The determination of the cryohydric temperature is thus quite simple, and its exactness depends on that of the thermometer, and on the certainty with which it may be affirmed that the temperature of the thermometer is identical with that of the mixture.

The determination of the concentration of the cryohydric brine produced, presents no difficulty, or only such as a chemist knows how to deal with, and as it is an operation which cannot profitably be attempted by any except a trained chemist with considerable laboratory experience, it need not be further described. The chemist may, however, be reminded that he has the choice of two ways of approaching the subject — the analytical and the synthetical. Further, he may either take his freezing mixture and allow it to melt, or he may make his presumed cryohydric solution, and allow it to freeze.

Cryohydrates of Salts forming Isomorphous Mixtures.—In the study of the cryohydric constants of mixtures, a peculiar interest attaches to mixtures of isomorphous salts which form mixed crystals, such as the nitrates of barium, strontium and lead, the nitrates of potassium and sodium.

We have seen that in the case of salts which, although they crystallise in the same system, do not form mixed crystals, as for instance NaCl and KCl or NH_4Cl, a mixture of any two is more soluble than either separately, and consequently the cryohydric temperature is lowered. It is easy to imagine why this should be. Looking to the analogy between salts in solution and gases, a certain mass of water when saturated with, say NaCl, is still virgin with regard to KCl which dissolves in it with ease. But the introduction of KCl, interferes with the free meeting of the particles of NaCl, which on the slightest lowering of temperature are prepared to unite and fall out as crystals. Therefore the effect of introducing this indifferent body KCl is to make the solution of NaCl, which was saturated, no longer saturated: in other words it depresses its temperature of saturation. But the cryohydric temperature of a saline solution is the freezing temperature of the saturated solution. This

has been lowered: therefore we see that the cryohydric temperature of a mixture of NaCl and KCl must be lower than that of NaCl alone; and it is quite independent of whether the cryohydric temperature of KCl is high or low.

Imagine now that KCl and NaCl, not only crystallise in the same system, but are isomorphous in the restricted sense, which is characterised by the formation of "mixed crystals." It is then obvious that in the saturated solution, the particle of NaCl when prevented from uniting with another particle of NaCl to form a crystal, will simply unite with the particle of KCl which stands in the way, and will crystallise. Consequently, if the solution of NaCl were originally not quite saturated, the introduction of the KCl, by increasing the amount of crystallisable material, would make it saturated. Hence, if KCl and NaCl were isomorphous and formed mixed crystals, the cryohydric temperature of a mixture of the two salts would be higher than that of the NaCl.

The nitrates of barium, strontium and lead are isomorphous salts which form mixed crystals. In boiling mixtures, it has been shown * that nitrate of strontium raises the condensing temperature of steam by 6°·53 C., and nitrate of lead raises it by 3°·29 C., while the mixture $\frac{Sr_2 + Pb}{3}(NO_3)_2$ raises it by 5°·98 C.; and the quantity of condensed steam required to produce the boiling saturated solution of the mixture is exactly the sum of the amounts required for the ingredients separately. In the case of the nitrates of strontium and barium, the elevation of the condensing point is not as great as with $Sr(NO_3)_2$ alone: the maximum temperature does not remain constant for a minute, and the condensed steam required to dissolve the mixture is about 25 per cent. more than is required to dissolve the salts separately.

Similarly in the case of freezing mixtures, the following cryohydric temperatures were observed: nitrate of barium −0°·7 C., nitrate of strontium −5°·75 C., and nitrate of lead −2°·7 C.; and the cryohydric temperatures of pairs of these salts in equal molecular proportions: nitrates of strontium and barium −5°·73 C., nitrates of strontium and lead −5°·23 C., and nitrates of lead and barium −2°·53 C.

The case of the isomorphism of salts which form mixed crystals is a feature of salts and solutions which has no analogy in the physics of gases.

* 'On Steam and Brines,' by J. Y. Buchanan, F.R.S. *Trans. R.S.E.* (1899), vol. xxxix. p. 547.

The following table gives the temperature at which ice melts in solutions of various chlorides. The concentration of the brines is indicated by the percentage of chlorine by weight in the solution. It is taken from the writer's paper 'On Ice and Brines.'

TABLE III.

Temperature at which Ice melts in Brine.	Name of Salt dissolved and Percentage of Chlorine in the Solution.			
	HCl.	KCl.	NaCl.	$CaCl_2$.
°C.				
− 35	15·26	..	..	..
− 30	13·98	..	..	15·97
− 25	12·60	..	..	14·47
− 20	11·00	..	..	12·65
− 15	9·17	..	11·10	11·29
− 10	7·02	..	8·40	8·93
− 5	4·15	..	4·72	5·65
− 4	3·41	..	3·87	4·67
− 3	2·68	3·00	3·02	3·70
− 2	1·85	2·00	2·02	2·70
− 1	..	1·02	1·02	1·50

In dealing with sea-water ice, it is well for the chemist and physicist to confine his attention in winter quarters to ice which he has seen freeze and with the whole of whose history he is himself acquainted. *Old* sea ice is nothing but a curiosity. Every lump of it in a pack has a different composition, and when the composition of a hundred lumps is known, unless their history is also known, it does not really advance our knowledge.

Everything connected with the natural history of *young* ice—its birth, its growth, and its decay—is of interest, and its study, in the light of the foregoing remarks, will afford continual and interesting occupation.

Land Ice and the Mechanics of Glaciers.—If ice is an important feature of the sea in Antarctic regions, it is a still more important feature of the land, and it should be the object of careful observation by the landing-party. The subject is a large one. The longer one studies ice the more one finds there is to learn about it, and the physicist or chemist who takes part in the Expedition should miss no opportunity of studying it in all directions. In order to do so with effect, he ought to have made preliminary studies of glaciers in Switzerland, where he finds every facility to his hand, and these studies should be made in winter as well as in summer.

Another educational preliminary for the members of a land expedition is to acquire as much skill as possible in ski running and the method of travel adopted by Nansen in crossing Greenland. For this purpose a short visit to Norway in winter would be useful. The way into the Antarctic interior will almost certainly be over land ice, and if it is the ice which is the parent of the great tabular bergs so well known from illustrations, it is probable that travelling over it will not be very difficult in so far as the nature of its surface is concerned. It has long been known that the glaciers of Greenland travel much more rapidly than those of Switzerland, but it is only since the publication of v. Drygalski's remarkable observations,* carried on throughout the year on the glaciers of the west coast of Greenland, that we know that in some cases the motion of the ice reaches the astonishing rate of 18 metres in twenty-four hours, and that this rate of motion is very little affected by the change of season. According to Drygalski, what chiefly affects the motion of a glacier is its mass. Great as are the glaciers of Greenland, there can be little doubt that the parents of the Antarctic tabular icebergs are many times greater. If conditions such as these exist on the Antarctic land, it is little wonder that the supply of tabular icebergs is so abundant. Dr. Arçtowski has described how, on the occasions when he landed on the rugged coasts visited by the *Belgica*, and the weather was calm, the thunder of falling ice was continuous. On Heard Island, during the short visit which the writer was able to pay it from the *Challenger*, the fall of ice from the western portion was also nearly continuous.

Since the days of Hugi and Agassiz, the intimate structure of glacier ice has been the object of much study by Continental and chiefly Swiss naturalists. Englishmen, though they frequent glaciers as much as any other nation, have generally ignored it. Tyndall, to whom we owe so much of our knowledge about ice, recognised the existence of the *grain* of the glacier, as it is called, but made no use of it in his speculations with regard to the nature of the motion of glaciers. As his theories are independent of this fundamental feature of the constitution of glacier ice, they must be *pro tanto* incomplete. The colour of the surface of a glacier, so dazzling in its whiteness that the inexperienced beholder is apt to suppose it covered with freshly fallen snow, is due to the disintegration of the compact blue glacier ice into its constituent grains under the influence of the radiation of the sun. There is no more instructive or more impressive experi-

* 'Grönland Expedition, 1891–1893, unter Leitung von Erich von Drygalski.' Berlin, 1897.

ment than to expose a block of compact blue ice taken from the interior of the glacier to the direct rays of a powerful sun. Such a block is easily obtained by penetrating into the grotto, from which the glacier stream issues, to such a distance that direct sky-light is shut out. Any of the blocks found there will do, and it is to be brought out and exposed on a rock. In twenty minutes or half an hour the block falls down into a heap of irregularly shaped pieces of ice, each of which is a grain and a single crystalline individual. In higher latitudes or in dull weather, the power of the sun is not sufficiently strong to effect this complete and striking dissolution, but it loosens the block into its grains, which will rattle if the block be shaken.

The writer has analysed blocks of ice from many Swiss glaciers, and weighed the individual grains. They are of all weights up to a certain maximum, which varies with the glacier and the part of it furnishing the ice. The largest that he met with was from the Aletsch glacier, and it weighed 700 grams. It is the size or weight of the largest grains that it is important to determine. Small grains are abundant in every glacier, and are a necessity in order that the larger ones may pack close. The size of the largest grains is what is referred to when we read that the grain of this glacier is large or of that one small. The shape of the grain is irregular, and no two of them are alike, but they fit into each other like a puzzle. They resemble a collection of vertebræ more than anything else. Indeed, if the disarticulated vertebræ of an animal, especially one with a long tail, were carefully packed into a box of a suitable size, so as to occupy the least possible space, the boxful of vertebræ would resemble the block of ice which has been loosened by a moderate sun, and would rattle, when shaken, in much the same way. If gelatine were allowed to run into the box and set, we should have a model of the block of ice before exposure to the sun. If the box of vertebræ were expcsed to the sun, the gelatine would be liquefied, and the mass would be loosened as in the case of the ice. What is it in the block of ice which corresponds to the gelatine in our illustration with the vertebræ? It is the slightly impure water which surrounds the grains and in which they *float* or try to float. Under the influence of cold, this impure water supplies pure ice to the grain with which it is in contact, while its freezing-point continually falls; finally its freezing-point and the temperature to which it is exposed reach a minimum, and the grain remains in contact, even in mid-winter, with a film of brine, which may be very minute. With rising temperature the grain begins to melt at the temperature at

which it ceased to freeze, it dilutes the brine, and raises its own melting point.* We see, then, that the grain of the glacier may be surrounded in summer by a relatively considerable envelope of water

* The following passages from the writer's paper on 'Ice and Brines,' pp. 143–146, explain this in greater detail. "All natural waters, including rain water, contain some foreign and usually saline ingredients. If we take chloride of sodium as the type of such ingredients, and suppose a water to contain a quantity of this salt, equivalent to one part by weight of chlorine in a million parts of water, then we should have a solution containing 0·0001 per cent. of chlorine, and it would begin to freeze and to deposit pure ice at a temperature of $-0°·0001$ C.; and it would continue to do so until, say, 999,000 parts of water had been deposited as ice. There would then remain 1000 parts of residual water, which would retain the salt, and would contain, therefore, 0·1 per cent. of chlorine, and would not freeze until the temperature had fallen to $-0°·1$ C. This water would then deposit ice at temperatures becoming progressively lower, until when 900 more parts of ice had been deposited, we should have 100 parts residual water, or brine, as it might now be called, containing 1 per cent. of chlorine and remaining liquid at temperatures above $-1°·0$ C. When 90 more parts of ice had been deposited we should have 10 parts of concentrated brine containing 10 per cent. of chlorine and remaining liquid as low as $-13°$ C. In the case imagined we assume the saline contents to consist of NaCl only, and with further concentration the cryohydrate would no doubt separate out and the mass become really solid. On reversing the operations, that is, warming the ice just formed, we should, when the temperature had risen to about $-13°$ C., have 999,990 parts of ice and 10 brine containing 10 per cent. of chlorine. Now, owing to the remarkable fact that pure ice in contact with a saline solution melts at a temperature which depends on the nature and the amount of the salt in the solution, and is identical with the temperature at which ice separates from a solution of the same composition on cooling, the brine liquefies more and more ice at progressively rising temperatures, until, as before, when the temperature of the mass has risen to $-0°·1$ C. it consists of 999,000 parts of ice and 1000 parts of liquid water containing 1 part of chlorine. The remainder of the ice will melt at a temperature gradually rising from $-0°·1$ to $0°·0$ C.

WATER CONTAINING 7 PARTS CHLORINE IN 1,000,000.

Temp. °C.	Water frozen. c.c.	Ice formed. c.c.	Brine remaining. c.c.	Ice and Brine. c.c.
T	V_1	v_1	V_2	v_2
− 0·07	99,000	107,979	1000	108,979
− 0·10	99,300	108,3[illegible]6	700	109,006
− 0·15	99,533	108,561	467	109,028
− 0·20	99,650	108,687	350	109,037
− 0·40	99,825	108,879	175	109,054

"In this table are given the volumes occupied by the ice (with inclosed brine) formed by freezing 100,000 c.c. (at 0° C.) of a water containing chloride of sodium, equivalent to 7 grms. chlorine in 1,000,000 cc. (at 0° C.)

"The *plasticity* of ice and the motion of glaciers receive a simple and natural explanation when we see, as in the table, that if the water from which this ice is produced contains no more than 7 parts of chlorine per million, it will in the process of thawing when the temperature has risen to $-0°·07$ C. consist to the extent of 1 per cent. of its mass of liquid brine or water. The water considered in the table is certainly not less free from foreign ingredients than rain or snow. It follows, therefore, that a glacier in a climate where the temperature is for the greater part of the year above 0° C. must have a tendency to *flow*, owing to the power of saline solutions to deposit ice and to dissolve it at temperatures below 0° C."

of comparative purity and high freezing-point, while in winter it is surrounded by a mere film of brine of comparatively low freezing-point *The difference between land ice and sea ice is one of degree and not of kind. Sea ice is mixed with much brine and flows easily: land ice contains little brine and flows with difficulty.*

A ship floats in the smallest basin as perfectly as in the largest ocean. We can imagine a dock being built round a ship, and so exactly moulded to its shape, that between the inner surface of the dock and the outer surface of the ship, the clearance shall be so small that a pitcher of water poured into it will float the ship. The floating of a grain in the inside of a glacier is of this kind, and as it is enclosed on all sides, it will press against the ice above it in preference to that beneath it.

This feature of glacier ice permits us to understand how glaciers can move, and begin to move, even when their temperature is very low. Before von Drygalski's work on Greenland, we had no trustworthy information regarding the temperature throughout the year of the inner mass of the ice of any glacier. He carried out, at regular intervals of time, a series of observations of the temperature at different depths below the surface of one of the Greenland glaciers, and parallel observations within the ice covering a neighbouring lake. These observations showed that the temperature of the glacier increases rapidly from the surface downward, and they render it probable that the greater part of the thickness of a Greenland glacier is, even at the coldest time of the year, at or near the ordinary temperature of melting ice.* The heat required to support this temperature can only be supplied by the friction of the grains of the ice, called into being by the motion of the glacier. The *inland ice* which forms the great reservoir for the supply of the glacier, was found to have little or no appreciable motion. Series of temperatures were not taken in its thickness, but, in the absence of motion, we may believe that the very low temperature at its surface penetrates far into its interior, if not to the very bottom. If the motion were dependent *only* on the lowering effect of pressure on the melting-point of pure ice, it would be difficult for such a mass of ice to *start* when it arrives at an outlet. The impurity of all natural water, and the effect which it has in lowering the melting-point of ice at ordinary pressures, remove this difficulty. However compact and solid the blue ice may look, there will always be *some* brine between its grains which will permit some yielding of its mass, which in its

* Compare Hugi, 'Ueber das Wesen der Gletscher und Winterreise in das Eismeer,' p. 51.

turn will produce a first generation of heat; this will produce a further yielding, and in due course a further generation of heat, and the effect of this initial agency, when combined with the powerful effect of fusion and regelation under conditions of very slight variation of pressure, is the extraordinary rate of motion observed in the glaciers of Greenland.

It has been pointed out that the whiteness of the surface of a glacier is due to what may correctly be termed sun burning or sun weathering. The icebergs which are met with at sea have an equally white surface; but where the interior is exposed, either in crevasses or in caves melted out by the waves, the deep blue colour of the fresh ice is visible. It is obvious that the whole of the surface of the glacier which is immersed in water at greater depth than that to which the sun's rays can penetrate must have the same blue colour, and it is equally obvious that when an iceberg turns completely over, it must stand out as an intensely deep blue mountain of ice among the multitude of sunburnt white ones. On one of the fine days during the sojourn of the *Challenger* in Antarctic waters, a striking and magnificent example of this was observed, but the cause of the blueness of the strange berg was quite unsuspected. If ice were collected by bombardment or otherwise, from such a berg, the grain would be large and well developed, and the ice would be quite compact and free from vesicles. In the region visited by Dr. Arçtowski, the glaciers and the icebergs were comparatively small and of an Arctic character. The distribution of snow, *névé*, and ice he describes as being similar to that in the Alps at a height of 3000 to 4000 metres. There appeared to be very little melting, yet the glaciers advanced steadily towards the sea. In the *Challenger* the writer observed at least one large tabular berg, which was melting freely on the top, and streams were cascading down the sides. In Spitzbergen the glacier streams often take large proportions; it will be interesting to know if in equally high Southern latitudes there is similar melting under the influence of the long polar day.

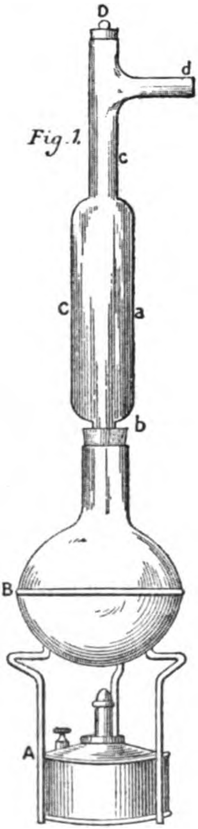
The Determination of the Temperature of Saturated Steam, and the Production of Higher Fixed Temperatures by the Condensation of Steam on Salts and in Saline Solutions.*

The method of determining the pressure of the atmosphere by the temperature of saturated steam has for some time ceased to be

* Chiefly a reprint of an article with the above title in the *Scottish Meteorological Journal.*

in common use. Yet it is one which is very simple in its practice and accurate in its results. In the course of an investigation into the boiling-points of aqueous solutions, the writer had frequent occasion to determine the boiling-point of pure water, or, more properly, the temperature of saturated steam at the barometric pressure of the moment; and he has arrived at a form of apparatus which gives this with great exactness and constancy, no matter how delicate the thermometer used may be.

Fig. 1.

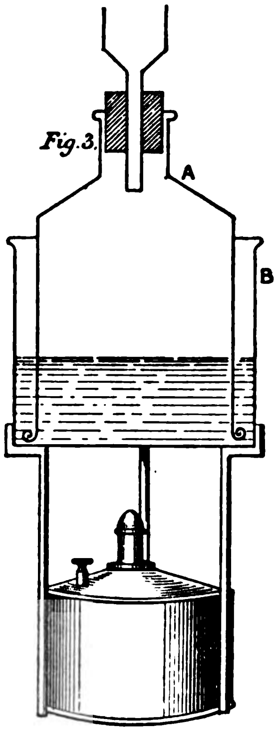


The instrument generally used for fixing or verifying the boiling-point of a thermometer is that of Regnault, which is described and figured in nearly every treatise on physics, e.g. Balfour Stewart's 'Lessons in Elementary Physics,' 1870, p. 151. For thermometers having their boiling-point not too near the bulb, this instrument gives fairly trustworthy results. There are, however, several disadvantages. First, the stem of the thermometer is not *wholly* immersed in the steam, and there is uncertainty about the temperature of the mercury in the portion of the stem inside the cork and projecting beyond it. It is disadvantageous and unnecessary to make the steam space of the apparatus of metal, and to dispose it in the form of an inner space and surrounding jacket. The want of transparency of the metal is an obvious disadvantage, and the jacketing is unnecessary, because the latent heat of steam is so great, that, with the supply of it which the boiler of Regnault's apparatus can furnish with any efficient lamp, a steam vessel of single envelope, under ordinary conditions, cannot be cooled by even a fraction of a degree below the temperature of saturated steam corresponding to the existing barometric pressure. Any cooling of the outside surface of the envelope is stopped at once and perfectly by the film of water continually descending along its inner surface, while the inner surface of the film is freely exposed to an abundant supply of saturated steam.

The object of the experiment is to produce an atmosphere of saturated steam, the tension of which is equal to the pressure of the atmosphere, and to have a trustworthy thermometer so immersed in it that it assumes, and retains without variation, the temperature of the steam.

For this purpose the supply of steam must be ample, while its means of escape into the atmosphere must be so free that no rise of pressure, due to over-supply of steam, can be produced. The steam, which is condensed on the walls of the steam tube, should run freely back into the flask without collecting at the bottom of the wide part of the steam tube. Therefore the tube making the connection with the boiling flask must be pretty wide; and the exit tube from the steam vessel must be a trifle wider still. Of the steam which enters the tube, part is condensed on the walls and keeps them at constant temperature, and the remainder passes away in a stream of good volume through the exit tube. With very little attention to the construction and management of the apparatus, every risk of cooling from without or heating from within is completely avoided.

Fig. 3.



Description of the Apparatus.—A general view of the apparatus is seen in Fig. 1. It consists of four parts: the lamp A, the steam generator B, the steam vessel or distilling tube C, and the thermometer D. The lamp shown is one of a French pattern, sold with the *Réchaud à double flamme forcée* of smallest size. It holds about 250 c.c. of spirit, and gives a flame powerful enough to work a much larger flask. The steam generator B is a flask made of spun copper, and of 500 c.c. capacity. A suitable charge is 300 c.c. of water. With such a charge, and heated by the French lamp, the water boiled in six minutes at an expense of 12 grms. of spirit. While keeping steam at the rate suitable for the experiment the lamp consumed 21 grms. of spirit in fifteen minutes, and evaporated 92 grms. of water. It is obvious that where gas is available a gas lamp may be used.

A very convenient lamp, especially for work out of doors, is the Swedish lamp for burning petroleum or paraffin oil under pressure, and with a blue flame. It is particularly useful when larger steam generators are used, such as the metal flasks made for the Napier's coffee machines, used in restaurants. One of the ordinary size holds 2 litres, and is a most useful article both in the camp and the laboratory.

Another and very convenient form of steam generator is shown in Fig. 3. A is a tubulated bell-shaped vessel of tinplate, which passes inside the slightly larger receiver B, which holds the water to be boiled. The rest of the apparatus is the same as in Fig. 1. This form of steam generator has many advantages, and in travelling the lamp can be stowed inside it.

The most important part of the apparatus is the steam tube or vessel C. The following are the dimensions of one which has been a good deal in use (Fig. 4).

Fig. 4.

The wide part (*a*) is 160 mm. long, and 41 mm. in diameter. The part (*b*) making connection with the steam generator is 60 mm. long, and 9·5 mm. wide. The upper portion (*c*) is 110 mm. long, and 15 mm. wide; and the exit tube (*d*) is 50 mm. long, and 10 mm. wide. It is connected with the flask by means of a well-fitting cork, which is preferable to indiarubber as it does not adhere to the hot metal. From the above measurements it results that the internal volume of the whole tube is 239 c.c., and its internal surface is 291·5 sq. cm. The weight of the tube is 109 grms.; and if its specific heat be 0·2, the weight of water thermally equivalent to it is 21·8 grms.

These dimensions are suitable for the thermometer which was used. The length of the tube has to be suited to each thermometer. For mountain work the thermometer should be graduated from 85° C. to 101° C. and should be divided into tenths of a degree, the space between each division being about a millimetre, so that the length of the scale would be 16 cm., and that of the whole thermometer about 20 cm. It is convenient also to have a thermometer divided into fiftieths of a degree. It is essential that the thermometer be read entirely in the steam. If any part of the mercury extends outside of the apparatus, it introduces an uncertainty which stultifies the use of very delicate instruments. Whatever the size of the tube may be, it is essential to see that all the parts are sufficiently wide and properly proportioned; there must be no resistance anywhere to the passage to the steam. The lamp should be regulated to keep up a brisk flow of steam of good volume through *d*. The thermometer then finds itself immersed in saturated steam of

atmospheric pressure contained in a vessel, the outer surface of which is glass, but the inner surface is a film of water continually renewed by steam condensing on it. So long as the full supply of steam is kept up, this continually renewed film of water, in contact with saturated steam, is a perfect protection against variation of temperature in the interior of the steam tube. When the steam first passes through the tube there is rapid condensation on the sides, and after that, on the thermometer, from which the water falls in a series of drops, which follow each other first slowly, then rapidly, then again more slowly, until, finally, a drop remains hanging from the lower extremity of the thermometer, and never falls. By that time the protecting film of water has established itself on the sides of the tube, and effectually guards the thermometer from external influence. If it were possible for the temperature of the thermometer to fall ever so little below that of the condensing temperature of the saturated steam in the tube, its temperature would be immediately restored by the condensation of some of the steam on the water which moistens its surface. If its temperature were to rise ever so little above the condensing temperature it would be immediately brought back again by the evaporation of some of the moisture on it. Consequently, when the boiling is in full operation, the thermometer is exactly at the temperature when the smallest possible increase of heat will cause evaporation, and the smallest possible decrease of heat will cause condensation. *But the boiling-point of a substance is the temperature at which it, as a vapour, condenses on itself as a liquid, and as a liquid evaporates into itself as a vapour.* Therefore, the temperature of the thermometer is exactly the boiling temperature of the water. Further, the whole enclosure is guarded by a surface of water in contact with saturated steam, so that its walls are necessarily also at the boiling temperature of the liquid, and it is impossible that the thermometer can be at any other temperature than that of the boiling liquid and condensing vapour. It follows, therefore, that for this purpose we may graduate our thermometer into thousandths of a degree, if we choose, and it is quite certain that the temperature of the thermometer will not differ by that amount from that of the medium. During an operation the steam tube is the ideal enclosure at constant temperature. When the thermometer has taken the temperature of the steam, it remains perfectly steady so long as the barometric pressure remains the same.

As evidence of the efficiency of the steam tube, the rate of generation of steam was varied from the highest to the lowest which was possible with the lamp. The thermometer divided into fiftieths of a

degree Centigrade was used, and the mercury stood at 100°·18; that is the top of the mercury was exactly in line with the centre of the division on the stem marking 100°·18 C. It occupied this position when steam was being generated at its highest rate of 8·4 grammes per minute, and never varied by a fraction of the width of a division line until the rate of steam generation had been brought so low that it issued as an exhalation, and not a stream. The rate was then 2·5 grammes per minute, and the top of the mercury fell to the lower edge of the line marking 100°·18 C., which may be taken to represent a temperature of 100°·179 C.

In this experiment the rate of passage of steam was varied from 2·5 to 8·4 grammes per minute, or over three-fold, and it produced no effect on the thermometer; therefore, the exit tube efficiently removed whatever amount of steam entered it, and offered no sensible resistance to it. No better evidence than this could be furnished of the perfect efficiency of the instrument for the purpose for which it was designed.

With regard to the relative advantages of the thermometer and the barometer in hypsometric work, this thermometer may be taken as an example. It is divided into fiftieths of a Celsius degree, the length of the degree being 35 mm. The tension of saturated vapour, of 100° C., is 760 mm., and of 99° C., it is 733·305 mm. giving a difference of 26·695 mm. pressure for a difference of 1° C. temperature. Thus, 26·7 mm. on the barometer are represented by 35 mm. on the thermometer. Converting the readings of the thermometer into the corresponding ones of the barometer, each division would correspond to about half a millimetre. At lower pressures the effect of change of pressure on the temperature of saturation is greater, and at higher pressures it is less. Thus, from Regnault's experiments, we have the difference of pressure which causes a difference of 1° C. in the temperature of saturated steam at different parts of the scale, as follows:

TABLE IV.—GIVING THE TEMPERATURE (Celsius) OF SATURATED STEAM T, at the Pressure P, and the Difference of Pressure D corresponding to 1° C. Difference of Temperature of Saturation.

T	P	D	T	P	D	T	P	D
°C.	mm.	mm.	°C.	mm.	mm.	°C.	mm.	mm.
0	4·600	0·335	50	91·982	4·483	140	2,717·63	76·19
10	9·165	0·591	60	148·791	6·776	160	4,651·62	117·26
20	17·391	1·045	80	354·643	14·155	180	7,546·39	171·87
30	31·548	1·766	100	760·000	26·695	200	11,688·96	241·50
40	54·906	2·867	120	1,491·280	46·730	220	17,390·36	327·07

This table shows how rapidly the tension of saturated steam rises, as compared with its temperature. It also shows that the lower the tension of the steam, the more efficient is the thermometer for indicating it. But, for hypsometric purposes, it must be remembered that the higher we climb on a mountain the greater is the height required to produce a given fall of the barometer.

That these two effects very nearly compensate each other is shown in Tables V. and VI.,* which give the temperature of boiling

TABLE V.—GIVING THE TENSION OF SATURATED STEAM in Millimetres and Inches, and the CORRESPONDING HEIGHTS ABOVE THE SEA in Metres and Feet, for TEMPERATURES in CELSIUS degrees.

Temperature of Saturated Steam.	Barometric Pressure.				Height above Sea-Level.			
	Millimetres.		Inches.		Metres.		Feet.	
° Celsius.								
85	433·0	..	17·05	..	4495	..	14,750	..
86	450·3	17·3	17·73	0·68	4182	313	13,734	1016
87	468·2	17·9	18·43	0·70	3871	311	12,724	1010
88	486·6	18·4	19·16	0·73	3562	309	11,718	1006
89	505·7	19·1	19·91	0·75	3255	307	10,717	1001
90	525·4	19·7	20·69	0·78	2950	305	9,720	997
91	545·7	20·3	21·48	0·79	2647	303	8,728	992
92	566·7	21·0	22·31	0·83	2345	302	7,740	988
93	588·3	21·6	23·16	0·85	2045	300	6,757	983
94	610·7	22·4	24·04	0·88	1747	298	5,778	979
95	633·7	23·0	24·95	0·91	1451	296	4,804	974
96	657·4	23·7	25·88	0·93	1157	294	3,834	970
97	681·9	24·5	26·85	0·97	865	292	2,869	965
98	707·2	25·3	27·84	0·99	575	290	1,908	961
99	733·2	26·0	28·87	1·03	287	288	952	956
100	760·0	26·8	29·92	1·05	0	287	0	952

water in Celsius degrees in Table V., and in Fahrenheit degrees in Table VI., and the barometric pressure, in inches and millimetres, which is equal to the tension of saturated steam at the particular temperature, with the height above the sea, in metres and feet, at which this barometric pressure would be found in a still dry atmosphere at the temperature of melting ice. It will be seen that throughout a range of 4500 metres, or 15,000 feet, a depression of the boiling-point by 1° C. corresponds very closely to an ascent of 300 metres, or 1000 feet. If the column of differences of the baro-

* These tables are compiled from Tables 20, 25, 33 and 34 of the Smithsonian Meteorological Tables, 1893. No. 844 of the Smithsonian Miscellaneous Collections.

TABLE VI.—GIVING THE TENSION OF SATURATED STEAM in Millimetres and Inches, and the CORRESPONDING HEIGHTS ABOVE THE SEA in Metres and Feet, for TEMPERATURES in FAHRENHEIT degrees.

Temperature of Saturated Steam.	Barometric Pressure.				Height above Sea-Level.			
	Inches.		Millimetres.		Metres.		Feet.	
° Fahr.								
185	17·05	..	433·1	..	4653	..	15,267	..
186	17·42	0·37	442·5	9·4	4476	177	14,681	583
187	17·81	0·39	452·4	9·9	4292	134	14,082	602
188	18·20	0·39	462·3	9·9	4113	179	13,493	589
189	18·59	0·39	472·2	9·9	3937	176	12,917	576
190	19·00	0·41	482·6	10·4	3756	181	12,324	593
191	19·41	0·41	493·0	10·4	3580	176	11,744	580
192	19·82	0·41	503·4	10·4	3406	174	11,175	569
193	20·25	0·43	514·4	11·0	3228	178	10,592	583
194	20·68	0·43	525·3	10·9	3054	174	10,021	571
195	21·13	0·45	536·7	11·4	2876	178	9,436	585
196	21·58	0·45	548·1	11·4	2701	176	8,863	573
197	22·03	0·45	559·6	11·5	2530	171	8,302	561
198	22·50	0·47	571·5	11·9	2355	175	7,728	574
199	22·97	0·47	583·4	11·9	2184	171	7,166	562
200	23·45	0·48	595·6	12·2	2013	169	6,604	562
201	23·94	0·49	608·1	12·5	1842	171	6,042	562
202	24·44	0·50	620·8	12·7	1670	172	5,480	562
203	24·95	0·51	633·7	12·9	1499	171	4,919	561
204	25·46	0·51	646·7	13·0	1332	167	4,369	550
205	25·99	0·53	660·1	13·4	1161	171	3,809	560
206	26·52	0·53	673·6	13·5	994	167	3,260	549
207	27·07	0·55	687·3	13·7	824	170	2,703	557
208	27·62	0·55	701·5	14·2	657	167	2,156	547
209	28·18	0·56	715·8	14·3	491	166	1,610	546
210	28·75	0·57	730·3	14·5	325	166	1,066	544
211	29·33	0·58	745·0	14·7	160	165	523	432
212	29·92	0·59	760·0	15·0	0	160	0	523

meter be inspected, it will be seen that the diminution of pressure for a given increase in altitude has fallen at 4500 metres to nearly one-half of what it is at the sea-level. Hence the efficiency of the thermometer as a hypsometric instrument, compared with that of the barometer, increases steadily with the altitude, so that for the greatest altitude the thermometer is the preferable instrument.

Fixed Temperatures produced by Steam in contact with Salt and Saline Solutions.—At the same atmospheric pressure, the tension of

the vapour of water is reduced, not only by lowering its temperature, but also, while the temperature is kept constant, by dissolving any salt in it. The tension of the vapour of pure water at 100° C. is 760 mm. If a small quantity of common salt or chloride of sodium be dissolved in it, the tension of its vapour is no longer 760 mm. at 100° C.; it is necessary to raise it to a higher temperature in order that its vapour may attain this tension. In proportion as more salt is added to the water, the higher is it necessary to raise the temperature of the water, or rather the resulting saline solution, in order to attain a tension of 760 mm. But there is a limit to the amount of salt which water can dissolve when boiling under a given pressure. When this amount has been added and dissolved, the solution is saturated and, so long as the atmospheric pressure remains the same, it is impossible to raise its boiling-point any higher. If heat is supplied, so as to keep the solution boiling, steam escapes from its surface, and crystals of salt separate out in the solution. The condition of the boiling solution is now precisely analogous with that of the freezing solution when, in the process of cooling, the cryohydric temperature and concentration have been reached. The temperature of the boiling solution remains constant, and steam and salt quit it *pari passu*. In the freezing solution the salt and ice are both solid, and remain associated in the cryohydrate. In the boiling solution the salt is solid and the steam is gaseous, and they part company of themselves.

The fact that steam produced by water boiling at 100° C., which under ordinary circumstances can produce by its condensation no higher temperature than that at which it was generated, should be able to raise the temperature of saline solutions many degrees above this temperature, appears at first sight paradoxical, and it was, in fact, largely disbelieved, in spite of the simplicity of the experiment to demonstrate it.

In a paper already referred to, the use of ice melting in saline solutions of definite nature and strength was strongly recommended as affording an absolute thermometric scale for such temperatures. Extending these researches to steam and brines, the writer found that the condensation of steam in saline solutions could be used for fixing, or verifying, temperatures above the boiling-point of water. Also steam water, and salt can be used to form *boiling mixtures*, exactly as ice, water, and salt are used to form freezing mixtures; and an independent and absolute thermometric scale is produced for high temperatures, just as with ice we have one for low temperatures.

These melting and condensing temperatures are intended to give fixed points of reference on the thermometer below the ordinary freezing- and above the ordinary boiling-point, and they can be chosen to suit the work in hand. Thus, if work is being done where temperatures about 108° or 109° C. are to be measured with the accuracy which is demanded of a thermometer on which the Centigrade degree occupies a length of one or perhaps two centimetres, it is not sufficient to verify the ordinary boiling-point, because the part of the scale of the thermometer used may be ten or fifteen centimetres distant from it, and to verify the scale by careful calibration entails great labour. It is, however, very simple to expose the thermometer in a vessel of the form about to be described to the action of steam condensing in a mixture of common salt and brine, which gives a perfectly fixed temperature at a given barometric pressure. And these conditions can be reproduced at any future time, and the readings of the thermometer in the immediate neighbourhood of this fixed temperature can thus be verified as accurately as if they had been as near to the ordinary boiling-point of distilled water.

For temperatures above the boiling-point of water it is convenient to use "boiling mixtures," where the dry salt is put in a suitable vessel holding a thermometer, and the steam is blown through it until the bulb of the thermometer is immersed in a boiling mixture of brine and solid salt, and the stem is immersed in its steam.

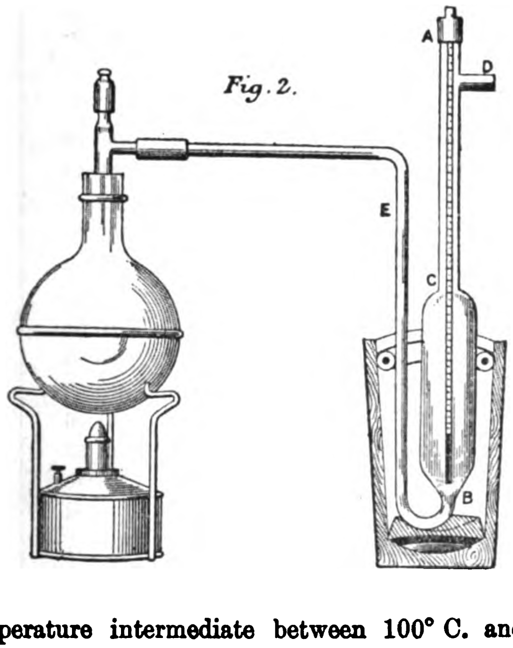
One of the most convenient salts for this purpose is chloride of sodium, on account of its almost uniform solubility at different temperatures. At ordinary atmospheric pressure it raises the condensing point of steam by 8°·4 C., or 15°·1 Fahr. If a weighed quantity of salt has been used and the apparatus has been also weighed, then by continuing to blow in steam after all the salt has been dissolved, and weighing the apparatus when the temperature has fallen to certain definite degrees, a series is obtained of the temperatures at which steam condenses in solutions containing definite amounts of salt. This has been done for a number of salts. It is a much more accurate way of determining the boiling-point of a solution than by boiling it over a lamp flame. This holds generally. *To determine the boiling-point of a liquid it should be boiled by its own steam.*

The apparatus used is shown with the boiling flask and lamp in Fig. 2. The steam tube is U-shaped; the one leg has a large body, C B, 15 cm. long and 4 cm. wide. This is continued upwards in the tube A C, which is 15 cm. long and 12 mm. wide. The exit

tube D has an internal diameter of 7 mm., and the entry tube E has also 7 mm. diameter, or slightly less. The dry salt is introduced into C B; the thermometer passes through a cork at A, and the bulb is covered by the salt at the bottom of C B. The tube is then weighed. It is then connected with the steam generator and steam blown through, which in a few minutes produces a magma of boiling brine mixed with salt, while the thermometer takes the maximum temperature, and retains it until the solid salt approaches complete solution.

The graduation of the thermometer thus receives a useful check at this part of the scale. If it is wished to verify the thermometer

Fig. 2.



at any temperature intermediate between 100° C. and 108°·4 C., steam can be passed through until the temperature of the boiling solution has fallen to the degree wished, and by weighing the apparatus, or determining the chlorine, the amount of steam condensed is found; and, as that of the salt is known, the strength of the solution, which boils at this particular temperature, under the observed barometric pressure, is obtained, and that temperature can always be again recovered independently of the thermometer with which the original observation was made.

The elevation of the boiling-point of a saturated solution of a salt above that of pure water is affected by the barometric pressure. For

chloride of sodium the rise may amount to as much as 8°·45 C. at the sea-level; and in the course of experiments made in Switzerland it has been found to fall to 8°·0 C. at a height of 2770 metres above the sea. If, however, we represent by t the boiling temperature of the saturated solution, and T the boiling-point of pure water at P, the barometric pressure at the moment: then, if p be the barometric pressure under which pure water would boil at temperature t, the ratio $p : P$ appears to be constant, and equal to 1·345.

TABLE VII.—GIVING THE BOILING TEMPERATURE OF PURE WATER, and the TEMPERATUREOF A BOILING MIXTURE OF STEAM AND CHLORIDE OF SODIUM, for Barometric Pressures between 550 and 770 Millimetres.

Barometric Pressure.	Temperature of Saturated Steam.	Tension of Saturated Steam of Temperature t.	Temperature of Boiling Mixture.	Rise of Boiling-Point of Saturated NaCl Brine.
P.	T.	$p = 1{\cdot}345\,P$.	t.	$t-T$.
Millimetres	°C.	Millimetres	°C.	°C.
770	100·37	1035·6	108·89	8·51
760	100·00	1022·15	108·50	8·50
750	99·63	1008·7	108·11	8·48
740	99·26	995·25	107·72	8·46
730	98·88	981·8	107·32	8·44
720	98·49	968·35	106·92	8·43
710	98·11	954·9	106·51	8·40
700	97·71	941·45	106·10	8·39
690	97·32	928·0	105·68	8·36
680	96·92	914·55	105·26	8·34
670	96·51	901·1	104·83	8·32
660	96·10	887·65	104·40	8·30
650	95·68	874·2	103·96	8·28
640	95·26	860·75	103·51	8·25
630	94·83	847·3	103·07	8·24
620	94·40	833·85	102·61	8·21
610	93·96	820·4	102·15	8·19
600	93·51	806·95	101·68	8·17
590	93·06	793·5	101·21	8·15
580	92·60	780·05	100·73	8·13
570	92·13	766·4	100·24	8·11
560	91·66	753·15	99·75	8·09
550	91·18	739·7	99·24	8·06

In Table VII. we find the barometric pressure (P), given for every tenth millimetre from 770 to 550 mm., and the corresponding temperature of saturated steam (T); under (t), the temperature of a

boiling mixture of steam and NaCl under the barometric pressure (P); under p ($= 1 \cdot 345\,P$), the calculated tension of saturated steam of temperature t; and under $t—T$, the excess of boiling-point of saturated NaCl solution above that of pure water under the given pressure. This table gives figures which agree closely with the results of the writer's observations in Switzerland at nine different altitudes, varying from 400 to 2773 metres. It appears that the alteration in the solubility of NaCl between the temperatures 91° C. and 100° C. is so slight that the relative depression of vapour tension is not sensibly affected.

The practical value of these results is that, if a thermometer be exposed to the action of pure saturated steam, and to a boiling mixture of steam and NaCl, and the temperature noted in each case, the difference of these temperatures, compared with the tabular value of $t—T$ for the existing barometric pressure, furnishes a direct and easily applied control of the graduation of the thermometer over the observed range.

TABLE VIII.—GIVING THE BAROMETRIC PRESSURE AT WHICH A BOILING MIXTURE OF STEAM AND CHLORIDE OF SODIUM HAS A CERTAIN TEMPERATURE; the Limits of Temperature being 109° and 99° C.

Temperature of Boiling Mixture.	Barometric Pressure.	Pressure corresponding to a difference of 0·1° C.	Temperature of Boiling Mixture.	Barometric Pressure.	Pressure corresponding to a difference of 0·1° C.
t	p	dp	t	p	dp
°			°		
109	773·4	..	104	650·9	..
108·5	760·2	2·60	103·5	639·8	2·22
108	747·4	2·40	103	628·7	2·22
107·5	734·9	2·50	102·5	617·8	2·18
107	722·4	2·50	102	607·0	2·16
106·5	710·2	2·44	101·5	596·3	2·14
106	698·0	2·44	101	585·7	2·12
105·5	686·1	2·38	100·5	575·3	2·08
105	674·2	2·38	100	565·1	2·04
104·5	662·5	2·34	99·5	555·1	2·00
104	650·9	2·32	99	545·1	2·00

For information about other salts in this respect, the reader is referred to the writer's paper on 'Steam and Brines.'

Before passing from this subject attention may be directed to the following interesting connection between the freezing and the boiling of saline solutions.

The temperature of a saline solution at its freezing-point is *raised* by melting ice in it, and the rate at which it raises the temperature of the solution is the less the greater the amount of ice melted. The more nearly the temperature of the solution approaches to 0° C., the greater is the amount of ice which must be melted in order to produce a certain rise of temperature. When the temperature of the solution is ever so little below 0° C., the amount of ice which has to be melted in order to produce the smallest rise of temperature is ever so great. But the temperature at which ice melts in a solution is the temperature at which the solution freezes. Therefore, for solutions containing the same amount of a salt, the *depression of the freezing-point* is the less the greater the amount of water present. In some cases the depression of the freezing-point is exactly proportional to the reciprocal of the amount of water present; in other cases it deviates slightly from exact proportionality in one sense or in the other.

The temperature of a solution at its boiling-point is *lowered* by condensing steam in it; and the rate at which it lowers the temperature of the solution is the less the greater the amount of steam condensed. The more nearly the temperature of the solution approaches the temperature at which saturated steam condenses on pure water, the greater is the amount of steam which must be condensed in order to produce a certain fall of temperature. When the temperature of the solution is ever so little above the boiling-point of pure water, the amount of steam which has to be condensed in order to produce the smallest fall of temperature is ever so great. But the temperature at which steam condenses in a solution is the temperature at which the solution boils. Therefore, for solutions containing the same amount of a salt, the *elevation of the boiling-point* is the less the greater the amount of water present. In some cases the elevation of the boiling-point is exactly proportional to the reciprocal of the quantity of water present; in other cases it deviates slightly from exact proportionality in one sense or in the other.

If T_f be the freezing-point of water, and t_f be the freezing-point of a solution which for a certain quantity of dissolved salt contains a quantity W_f of water, then the value of the product $W_f\,(T_f - t_f)$ is constant in the case of some salts; in the case of others it increases as W_f, or the amount of water, increases; in the case of others again it decreases as the dilution increases. But the deviations from constancy are never great even in nearly saturated solutions.

If T_b be the boiling-point of water, and t_b be the boiling-point of a solution which, for a certain quantity of dissolved salt, contains a

quantity W_b of water, then the value of the product $W_b (t_b - T_b)$ is constant for some salts; in the case of others it increases as W_b, or the amount of water, increases; in the case of others again it decreases as dilution increases.

The product of a mass into a temperature is a quantity of heat. Therefore, the expressions $W_f (T_f - t_f)$ and $W_b (t_b - T_b)$ represent quantities of heat.* The physical meaning or interpretation of the statement that either of these products is constant, when the proportion between the factors in it varies, is that *water can contain more heat without boiling, and less heat without freezing, in proportion to the amount of salt dissolved in it.*

This is a general law of which Blagden's law of freezing is a particular case.

The phenomena accompanying the freezing and the boiling of saline solutions have always been perplexing. Salt-water ice melts at a lower temperature than fresh-water ice, and it is impossible to prepare pure water from it; therefore it was held by some that the salt must belong to the ice. But by skilfully managing the melting, the temperature may approach very near to 0° C., and the water prepared from it may contain very little salt, and may be drinkable; therefore it was held by others that the salt belonged to the brine. The available experimental data did not conclusively prove either that the salt belongs exclusively to the ice or to the brine. The proof that the salt does not belong to the ice was furnished by showing that snow or other pure ice, of independent origin, which contains no salt, behaves in a saline solution in exactly the same way as the alleged ice formed by freezing the solution.

Again, regarding the boiling of saline solutions, it was observed that the boiling temperature of a saline solution is higher than that of pure water, that the steam produced by it is pure steam, and that a thermometer in the steam above the boiling solution shows the same temperature as it would if immersed in steam above pure boiling water. The question which vexed many minds, was: When the steam is just quitting the solution, has it the temperature indicated by the thermometer immersed in the steam alone, or has it that of the thermometer immersed in the boiling solution? It was held by some that the temperature of the thermometer immersed in steam must be held to prove that the steam leaves the solution at the temperature of pure boiling water. Others contended that, although we have no means of knowing at what temperature steam would condense on *perfectly dry* glass, the moment there is the slightest

* 'Steam and Brines,' p. 544.

moisture on it the steam is condensing on water, and we know exactly what that temperature is: it is and it must be the temperature of pure boiling water under the existing conditions, and it proves nothing as to the temperature at which the steam actually quitted the solution.

The proof that the steam must quit the solution at the temperature of the boiling solution is furnished by the following considerations. We observe that when we blow pure steam into a saline solution, it raises its temperature above that of pure boiling water, and until a certain maximum temperature is reached, which depends on the relation between the salt and the water present. As steam continues to pass and to condense in part, owing to the lower temperature of the air outside, the temperature of the boiling solution falls gradually as the amount of water present increases by the condensation of steam. We see then that pure steam of independent origin is condensed by a saline solution having a temperature higher than that of boiling water at the moment, and lower than that of its own boiling-point; but it is admitted that the boiling saline solution produces pure steam which must be in contact with the solution which produces it. If the steam so produced is at the temperature at which it would be produced by pure water boiling under the same conditions, then it must *by contact* cool some of the solution below its boiling-point. But it has been shown that pure steam in contact with a saline solution, the temperature of which is ever so little below that of its boiling-point, is condensed by it, and has its temperature raised by such condensation. But steam of a lower temperature than that of the boiling solution cannot be both condensed and generated under the same conditions. We see that it is condensed; therefore it cannot be liberated unless its temperature is at least as high as that of the boiling solution. There is no reason to suppose that it can be any higher; therefore, *the temperature of the steam leaving a boiling saline solution is the same as that of the boiling solution itself.*

The Determination of the Density of Sea Water by means of the Absolute-Weight Hydrometer.

Though the waters of different localities of the ocean differ in the amount and nature of the saline matter dissolved in them; it has been found that the nature of the dissolved contents can, for almost all purposes, be held to be constant; and that, therefore, a water is generally characterised by the amount of its dissolved con-

tents—its salinity. This salinity, within the limits met with in the ocean, varies directly with the density. The density can be determined with great accuracy even at sea by means of a suitable hydrometer. It has been found, also, that the preponderance of chlorides over other salts in sea water is such that the salinity of a sea water varies sensibly as the amount of chlorine which it contains. The writer always uses the hydrometer, with which he can make sure of the density to one or two units in the fifth decimal place, relatively to that of distilled water at the same temperature determined at the same time and with the same instrument. The chlorine method is quite unsuitable for use at sea, because the quantity of chlorine is so large that the amount of water convenient for analysis is too small for exact measurement, and it cannot be weighed at sea. Then at sea nothing is free from chlorine—the air and everything is impregnated with chlorides; so that, as a means of specifying and distinguishing oceanic waters, the writer considers the chemical method untrustworthy, except when made with all refinements in a laboratory on land. There is, of course, no comparison in the amount of time required, compared with the hydrometric method.

The most important factor is the weight of the hydrometer. The following particulars refer to the determination of the weight of the instrument, 1893, No. 16.

The weight *in vacuo* of the hydrometer was determined independently on three different days as follows:—

November 25, 1893.—Barometer 736·98 mm.; temperature, dry bulb 10°·3 C., wet bulb 9°·0 C.

Weight of hydrometer in air	182·5875	grms.
Add weight of displaced air	0·1960	„
Weight *in vacuo* of hydrometer . . .	182·7835	„

December 9, 1893.—Barometer 730·35 mm.; temperature, dry bulb 6°·0 C., wet bulb 4°·6 C.

Weight of hydrometer in air	182·5850	grms.
Add weight of displaced air	0·1975	„
Weight *in vacuo* of hydrometer . . .	182·7825	„

December 16, 1893.—Barometer 754·64 mm.; temperature, dry bulb 11°·0 C., wet bulb 9°·9 C.

Weight of hydrometer in air	182·5828	grms.
Add weight of displaced air	0·2002	„
Weight *in vacuo* of hydrometer . . .	182·7830	„

Taking the mean of these three independent and concordant weighings we obtain for the

Weight *in vacuo* of hydrometer . . . 182·7830 grms.

The weight of the hydrometer is also the weight of the water which it displaces. In the manufacture of the instrument its weight is so adjusted that in distilled water of 30° C. it floats with the water line at the lowest division, 0 mm., on the stem. Let us assume that it does so exactly. Then the weight of the distilled water of 30° C., which it displaces, is 182·7830 grms. If now it be immersed in a saline solution, such as sea water, having a temperature of 30° C., it will not sink so deeply into it. In order to immerse it up to 0 mm. on the stem it will be necessary to add weight, let us say 4 grms.; then we have at once the weights of equal volumes of distilled water and of the sea water, both at the same temperature 30° C.: they are 182·7830 and 186·7830. The quotient, or 1·0218839, is the specific gravity of the sea water at 30° C., referred to that of distilled water of the same temperature as unity. Hence in order to get an accurate determination of the specific gravity of the sea water, we require to know only the weight of the instrument which floats at a given water line. In order to avoid the use of small weights which are necessary to make the hydrometer always float at the *same* water line, the stem has been divided into one hundred water lines, each 1 mm. apart. The external diameter of the stem is about 3 mm., so that the displacement in distilled water of the divided part is about 1 grm. Let us imagine that it is so exactly. Let us now float the hydrometer in distilled water of 30° C.: it floats at 0 mm. Let us now add 0·5 and 1·0 grm. respectively, and we find that the immersion is increased to 50 and 100 mm. respectively, and the three weights of distilled water displaced are 182·7830, 183·2830 and 183·7830 grms. respectively. Now let us float the instrument in the sea water of 30° C., and we require 4 grms. to make it float at 0 mm. If we add 0·5 and 1·0 grm., these weights will produce slightly less additional immersions than they did in distilled water. Let the immersions be to 49 mm. and 98 mm. respectively. We have then the elements of three independent determinations of the specific gravity of the sea water at 30° C., referred to distilled water of the same temperature as unity. The first is the same as before, 1·0218839.

In the other two cases the displacements are not exactly the same. They could be made the same by adding about 0·01 and 0·02 to the additional weights respectively. But it is inconvenient to have to work with these small weights. As 1 mm. of this stem corresponds to a displacement of 0·01 grm. distilled water it is evident that by subtracting 0·01 and 0·02 grm. from the weights of the hydrometer floating in distilled water we get the weights of dis-

tilled water displaced when the instrument is floating at 49 mm. and 98 mm. respectively, and we have only to perform the division as before. The two pairs of weights are 183·273 and 187·283, and 183·7630 and 187·8830, which give the quotients 1·021879 and 1·021877. Working according to this plan and using no weights lighter than 0·1 grm., we can easily get two parallel series of nine independent determinations each, of the weights of equal volumes of any two liquids and especially of distilled water and sea water having the same temperature. These depend on nothing but the weight of the hydrometer. The determination of a weight is one of the physical operations which can be performed with the greatest exactness.

It may be here pointed out that the weight which causes the displacement of the hydrometer is its own weight *plus* the weight of the liquid meniscus which it carries on the stem at the line of flotation. It is impossible to weigh or measure this exactly, but we are only concerned with the question whether and in how far it can effect the exactness of our determination of the specific gravity of sea-water. It may be taken that the volume of the meniscus of distilled water does not differ by a measurable amount from the volume of the sea-water meniscus, therefore, the weights of the meniscuses will be in the proportion of their specific gravities. Imagine for one moment that the volume of the meniscus is 1 c.c., or equal to the volume of the whole of the stem of the hydrometer; then, in our example, we should have for the displacing weight in distilled water, 182·783 + 1 = 183·783 grms., and for that in sea-water, 186·783 + 1·022 grm. = 187·805 grms., and the quotient of these is 1·0218845. When no allowance was made for the weights of the meniscuses, the quotient was 1·0218839; there is, therefore, a difference of six in the seventh decimal place. The volume of the meniscus is not more than about 0·01 c.c., so that the error due to neglect of the weights of the meniscuses affects no higher place than the ninth.

The specific gravity of a sea-water, as determined by the absolute-weight hydrometer, is a fraction of which both the numerator and the denominator consist, for the most part, of the weight of the glass instrument. It follows, that there may be a considerable error in the determination of this weight, without the exactness of the quotient or the specific gravity being sensibly impaired. For instance, let us imagine that an error of 1 grm. has been made in the determination of the weight of the instrument, so that it weighs 181·783 grms, in place of 182·783 grms.; then, continuing the

above example, the specific gravity is $185 \cdot 783 \div 181 \cdot 783 = 1 \cdot 0220042$, in place of $1 \cdot 0218845$, showing a difference of $1 \cdot 97$ in the fifth decimal place. An error of 1 centigramme would therefore affect only the seventh, and an error of 1 milligramme, only the eighth decimal place.

Exception having, at one time or another, been taken to the principle of the absolute-weight hydrometer, the writer is convinced that it is not superfluous to direct attention to the above elementary arithmetical considerations.

It is not always convenient to make parallel observations in distilled water in the case of every sea water examined. Therefore, for common use, the results of a number of series of observations of the hydrometer in distilled water of different temperatures have been taken and interpreted in the above sense as giving the displaced volumes for the divisions of the stem, and the temperatures in question. Kopp's table of the thermal dilatation of distilled water has been used. It is unnecessary to go into all the details of this calculation. The results for this hydrometer, No. 16, taken as example, are given in the following pages.

The stem is divided into millimetres for a length of 100 mm. Its external diameter is about 3 mm. Its displacement is ascertained by floating the hydrometer in distilled water of given temperature, and adding successively weights, increasing by 0·1 grm. The result of the determinations is given in the following table:—

Interval on Stem. Millimetres.		Volume of Interval. Cub. centimetres.
0 to 10	.. ..	0·1049
10 20	.. ..	0·1036
20 30	.. ..	0·1065
30 40	.. ..	0·1031
40 50	.. ..	0·1014
50 60	.. ..	0·1077
60 70	.. ..	0·1069
70 80	.. ..	0·1043
80 90	.. ..	0·1047
90 100	.. ..	0·1006
0 to 100		1·0437

From this table giving the volume of successive lengths of 10 mm. of the stem, a table is to be constructed giving the volume of the immersed portion of the stem for every millimetre on it. There will be 101 entries in this table. The first will be 0 mm. and 0 c.c., the eleventh 10 mm. and 0·1049 c.c., and the last 100 mm. and 1·0437 c.c.

The volume of the hydrometer, when immersed just up to the

lowermost division 0 mm. on the stem, was determined at several different temperatures with great care. The result is given in the following table:—

Temperature.		Displaced Volume.		Dilatation per °C.
21°·22 C.	..	183·4271 c.c.	..	—
10°·95 C.	..	183·3819 c.c.	..	0·0045 c.c.
8°·99 C.	..	183·3759 c.c.	..	0·0032 c.c.
5°·10 C.	..	183·3600 c.c.	..	0·0039 c.c.
11°·05 C.	..	183·3842 c.c.	..	0·0039 c.c.

Hence the volume of the body of the hydrometer, when immersed up to 0 mm. on the stem, is 183·3842 c.c. at 11°·05 C., and its dilatation per °C. is 0·0039 c.c.; whence we have the *volume of body of hydrometer at 0° C.* = 183·3411 c.c.

As the dilatation is 0·0039 c.c. per °C., we have—

Volume of body of hydrometer is	183·3411 c.c. at	0° C.
	183·3606	5°
	183·3801	10°
	183·3996	15°
	183·4191	20°
	183·4386	25°
	183·4581	30°

A similar table of volumes for every degree can be constructed.

The constants of hydrometer (1893) No. 16 are therefore—

Weight of hydrometer *in vacuo*	182·7830 grms.
Volume of body up to 0 mm. on stem at 0° C. . . .	183·3411 c.c.
Dilatation per 0° C.	0·0039 c.c.
Average volume of 1 mm. on stem	0·010437 c.c.

The volume of the body of the instrument at 15° C. is 183·3996 c.c. This is the volume which it displaces when floating exactly at 0 mm. on the stem at this temperature. In a liquid of less density, but of the same temperature (15° C.), it sinks until all the divided part of the stem is immersed, and remains stationary at 100 mm. The volume of this liquid which is now displaced is 183·3996 + 1·0437 = 184·4433 c.c. The weight of the hydrometer is the same in both cases, namely, 182·7830 grm. Then we have ascertained that at 15° C. 182·783 grm. of the first liquid have a volume of 183·3996 c.c., and that the same weight of the second liquid at the same temperature occupies a volume equal to 184·4433 c.c. From these figures we find the weight of 1 c.c. of each liquid at 15° C. to be 0·996638 grm. for the first or denser liquid, and 0·990998 grm.

for the second or lighter liquid. The difference is 0·005640 grm., and this corresponds to the immersion of the whole of the stem, which is divided into 100 mm. Therefore the difference of density corresponding to a difference of immersion of 1 mm. is 0·000056. If we consider a difference of immersion of one-tenth of a millimetre, it corresponds to a difference of density of 0·0000056. This example gives at once an idea of the capability of the instrument.

Additional weights.—In order to be able conveniently to increase the weight of the hydrometer, a set of weights is supplied, of such a form that they can be placed on the top of the exposed stem. They are made of wire, in the form of spirals and of rings. The following are the particulars of a set:

Spirals of brass	7·0, 5·0 and 3·0 grms. respectively.
Rings of brass	1·0 and 0·5 grms. respectively.
Spirals of aluminium . .	1·0, 0·5, 0·2, 0·1 and 0·05 grms. respectively.
Rings of aluminium . .	0·1, 0·1, 0·1, 0·1 and 0·1 grms. respectively.

This set of weights has been designed so that, for varying the weight in distilled water, one aluminium spiral, which will carry the lighter aluminium rings as required, will be sufficient, and for varying the weight in sea water, one brass spiral will be sufficient, rings of brass or aluminium being added as required.

An example has already been given of a determination of specific gravity when parallel series of observations are made in the sea water and in distilled water of the same temperature. In the following example the volume of the hydrometer up to every division of the stem, and for all temperatures, from 0° to 30° C., is taken as known. It has been deduced from a number of series of observations on distilled water in the way just described. The sample of sea water has the temperature of the air in the room or laboratory. This is essential. If it is inconvenient to wait until the water has acquired this temperature then a coarser and less valuable hydrometer should be used. After the temperature of the water has been observed, the hydrometer is floated in it, with sufficient additional weight, say 5 grms., to immerse the stem to one of the lower divisions of the stem—let us say 3; then let 0·4 grm. be added and let it be immersed to 42, and for the third observation let a further weight of 0·4 grm. be added, and let it now float at 80. The hydrometer is then removed, dried and replaced in its box, and the temperature of the water is again taken. It must not have varied more than 0·2 C., in which case the mean between the temperature at the beginning and that at the end can be used.

Let this mean temperature be 20° C., and we have for the first determination—

Volume of body of hydrometer at 20° C.	183·4191 c.c.
Volume of immersed stem 3 mm.	0·0315 c.c.
Total immersed volume	183·4506 c.c.
Weight of displacing hydrometer	187·7830 grms.
Density or weight of 1 c.c. of the sea water at 20° C. .	1·023616

For the second determination we have—

Volume of body of hydrometer at 20° C.	183·4191 c.c.
Volume of immersed stem 42 mm.	0·4383 c.c.
Total immersed volume	183·8574 c.c.
Weight of displacing hydrometer	188·1830 grms.
Density or weight of 1 c.c. of the sea water at 20° C. .	1·023522

For the third determination we have—

Volume of body of hydrometer at 20° C.	183·4191 c.c.
Volume of immersed stem 80 mm.	0·8384 c.c.
Total immersed volume	184·2575 c.c.
Weight of displacing hydrometer	188·5830 grms.
Density or weight of 1 c.c. of the sea water at 20° C. .	1·023475

The mean of the three densities is 1·023538.

This is the density at 20° C.; or it is the specific gravity at that temperature, that of distilled water at 4° C. being unity.

Having obtained the density at 20° C. it will be required to find the density which the water has at some other temperature; for instance, the standard temperature which for all the *Challenger* waters was taken as 15°·56 C., or 60° Fahr. The reason for the adoption of this standard temperature was that, when the *Challenger* sailed, the most trustworthy tables for the purpose were those of Hubbard, and he used 60° Fahr. as his standard temperature. It is, however, also the most suitable temperature to which to reduce observations of density made in temperate regions, because about as many observations will have to be corrected *up* as have to be corrected *down*. Looking to the fact that the ocean waters contained between the two tropics are of greater volume than all the remaining waters on the globe taken together, it would be more suitable for a universal common temperature of reduction to take the mean temperature of the air at sea between the tropics. This would be about 22°·5 C.,*

* See 'A Retrospect of Oceanography during the last Twenty Years,' by J. Y. Buchanan, F.R.S., in the Report of the Sixth International Geographical Congress, held in London, 1895, where this subject is discussed.

so that for temperate and tropical waters 20° C. would be a very suitable common temperature of reduction.

In Arctic and Antarctic seas it might be well to reduce the observed densities to a common temperature about the mean temperature of the waters in their place. For this purpose 0° C. might be taken. It is only in the restricted areas of the Arctic and Antarctic seas that the adoption of 0° C. as the common temperature of reduction has any justification, because it is only there that the prevalent temperature is such that the corrections *up* to 0° C. would ever occur, and that very seldom. In all exact work corrections are to be avoided if possible. When they are unavoidable they are to be made as small as possible, and, if possible, they should balance each other. The standard temperature should be the mean of those most likely to occur, and we have seen that, as a general standard temperature for all the oceanic waters, 20° C. would be suitable. To adopt, as has been proposed, 0° C. or the extreme temperature in one direction, as the common temperature to which to reduce all observed densities, is contrary to the scientific canon.

Table IX. gives in units of the fifth decimal place the difference between the density at 15°·56 C. of an average sea water and its density at any other temperature between 0° C. and 30° C. It is compiled chiefly from Ditmar's observations, and the average sea water had a density of 1·02600 at 15°·56 C. We will apply it to the reduction of our numerical example. The density, that is, the weight of 1 c.c., or the specific gravity of the water referred to the density of distilled water at 4° C. as unity, is at 20° C. 1·02354. At 20° C. the density of sea water is less than it is at 15°·56 C; therefore, in order to find the density of the water at 15°·56 C., we must *add* the tabular difference, namely, 0·00110 to 1·02354, and we have 1·02464 as the density at 15°·56, often represented by the symbol ${}_4S_{15\cdot56}$. If now we wish to know its density at 0° C., we have to add the tabular difference 0·00218 to the density at 15°·56 C., namely, 1·02464, and we have 1·02682 as the density at 0° C. To reduce directly from density at 20° C. to density at 0° C., we should have to add the sum of the differences, or 0·00328 to 1·02354. The reader will see that in using 0° C. as a general standard temperature, the errors in the reduction are all in one direction, and densities are not observed below 0° C. which would enable us to introduce something to counterbalance it. Supposing that the temperature of the water *in situ* is 23°·4 C., then the density *in situ* is 1·02464 – 0·00203 = 1·02261. If the tempera-

ture *in situ* is 4°·3 C., then the density *in situ* is 1·02464 + 0·00187 = 1·02651. These examples will make the use of the table perfectly plain.

Having described the construction and the use of the absolute weight hydrometer, the following general observations regarding its

TABLE IX.—GIVING IN UNITS OF THE FIFTH DECIMAL PLACE THE DIFFERENCE BETWEEN THE DENSITY AT 15°·56 C. OF AN AVERAGE SEA-WATER AND ITS DENSITY AT ANY OTHER TEMPERATURE BETWEEN 0° C. AND 30° C.

	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°
·0	218	213	207	199	190	179	168	155	141	126	110	92	74	54	34	13
·1	218	213	206	198	189	178	167	154	140	125	109	91	72	52	32	11
·2	217	212	205	197	188	177	166	153	138	123	107	89	70	50	30	9
·3	217	211	205	196	187	176	165	151	137	122	105	87	68	48	28	7
·4	216	211	204	195	186	175	164	150	135	120	103	85	66	46	26	5
·5	216	210	203	195	185	174	163	148	184	119	102	84	64	44	24	2
·6	215	209	202	194	184	173	161	147	132	117	100	82	62	42	22	..
·7	215	209	201	193	183	172	160	145	131	116	98	80	60	40	20	..
·8	214	208	201	192	132	171	158	144	129	114	96	78	58	38	18	..
·9	214	207	200	191	181	170	157	142	128	112	94	76	56	36	16	..
	15°	**16°**	**17°**	**18°**	**19°**	**20°**	**21°**	**22°**	**23°**	**24°**	**25°**	**26°**	**27°**	**28°**	**29°**	**30°**
·0	..	10	33	58	84	110	137	164	192	220	249	279	310	341	373	405
·1	..	12	36	61	87	113	140	167	195	223	252	282	313	344	376	408
·2	..	15	38	63	89	115	142	170	198	226	255	285	316	347	379	411
·3	..	17	40	66	92	118	145	172	200	229	258	288	319	351	383	415
·4	..	19	43	68	94	121	148	175	203	232	261	291	322	354	386	418
·5	..	22	46	71	97	123	150	178	206	235	264	294	325	357	389	421
·6	1	24	48	74	100	126	153	181	209	237	267	298	329	360	392	424
·7	3	26	50	76	102	129	156	184	212	210	270	301	332	363	395	427
·8	5	28	53	79	105	132	159	186	214	213	273	304	335	367	399	431
·9	8	31	56	81	107	134	161	189	217	246	276	307	338	370	402	434

usefulness are taken from the 'Retrospect of Oceanography' (1895) already referred to:—

"The hydrometer which I constructed for the *Challenger* expedition, and used during the whole of it, gives absolute results. By its means, the weights of equal volumes of the solution and of distilled water of the same temperature are determined directly. It is neither more nor less than a pyknometer, where the volume of liquid *excluded* up to a certain mark is weighed instead of

that *included* up to a similar mark. In the pyknometer, the internal surface per unit of length of the stem can be made smaller than the external surface per unit of length of the stem of the hydrometer. On the other hand, the volume of the hydrometer can safely be made many times larger than that of the pyknometer, the dimensions of which must always be kept small on account of the difficulty of ascertaining its true temperature, which must be a matter of guess-work, because it is not measured directly. The temperature of another mass of liquid is measured, and the two are assumed to be identical. With the hydrometer, the liquid being in large quantity and outside of the instrument, its temperature can be immediately ascertained with every required accuracy.

"Again, for every determination with the ordinary pyknometer, the weight of the liquid contained in it has to be determined by a separate operation of weighing. With the hydrometer the weight of the liquid displaced, being always equal to its own, is determined once for all by repeated series of weighings, where every refinement is used to secure the true weight of the instrument. This weight can then be increased at will by placing suitable small weights on the upper extremity of the stem. Their weight is also most carefully determined once for all, so that at any moment the total weight of the displacing instrument is accurately known.

"In determining the density of a sea water in an expedition, only the absolute-weight hydrometer should be used. The samples of water should be stored in the laboratory where the observations are going to be made, and they should have sensibly the same temperature as the air while the observations are being made. If the motion of the ship is at any time too violent for it to be convenient to make the observations, then a sufficient supply of bottles should be at hand to keep the samples until the motion becomes less without interfering with the collection of other samples. When the water is in the cylinder, its temperature is carefully taken with a trustworthy thermometer, which must be divided into tenths of a Centigrade degree. The thermometer is then removed, and the hydrometer immersed and loaded with small weights, until the water-level rises to one of the lower divisions of the scale. It is unnecessary to point out that the water in the cylinder must be at rest, that the stem of the hydrometer must be sheltered from wind, that everything must be clean, and that the ordinary precautions usually observed in every physical or chemical laboratory are to be observed. Having obtained the first reading, further small weights are added by steps of 0·1 grm. until at least nine observations have been obtained. Sometimes it is

convenient to use the 0·05-grm. weight near the top or bottom of the stem. Care is taken that the stem of the hydrometer is wetted for a distance of 1 or 2 mm., but not more, above the division where the hydrometer is going to float. This is an essential precaution for ensuring precision. When the last observation, which must be the one nearest the upper extremity of the stem, has been made, the small weights are removed, and the hydrometer lifted out and put in safety, and the temperature again taken with the thermometer. It should not differ from the temperature found at the beginning by more than 0°·3 C., and in work making any pretentions to accuracy, it should not exceed 0°·1 C. If a difference of temperature amounting to 0°·3 C. is observed, and the temperature itself is above 20° C., then the mean temperature must not be taken and used for the nine observations, but the 0°·3 C. must be distributed over them, and the temperature, which the water had at the time of each observation, used. The difference affects the fifth place of decimals.

"Whether at sea or on land, I always log the time in my laboratory work. A series of observations with the hydrometer as above described takes on an average about twelve minutes; but in that time at least nine quite independent observations have been made of the density of the water. If a sufficient number of observations have already been made with the hydrometer in distilled water of the same or nearly the same temperature, they may be used for giving the specific gravity of the water. If they have not, or if the determination is of especial importance, then a precisely similar series of observations must be made in distilled water of the same temperature, and variations of temperature amounting to 0°·3 C. are then inadmissible.

"When the corresponding series of observations has been made in distilled water, and they have had the small stem correction applied so as to give the displacing weight in distilled water at the exact stem divisions observed in the sample water, we have nine pairs of readings, each pair giving the weights of equal volumes of distilled water and of the sample, and therefore each pair giving by their ratio an independent determination of the specific gravity of the sample, referred to that of distilled water of the same temperature as unity. The mean of the nine observations gives a result which, according to the doctrine of probabilities, should have a precision three times greater than that of a single observation. Although much may be done to avoid a large range of temperature of observation, there will always be some difference in the temperatures at which the specific gravity of the various samples is observed, and as

a similar variation would take place in the unit to which they are referred, we effect a reduction to their value, taking the density of distilled water at 4° as unity. This is obtained by multiplying the figures obtained as above for the specific gravity by the weight of 1 c.c. of distilled water at the temperature of observation. This is one of the physical constants which have been determined with the greatest care and presumably with the greatest precision, and therefore, if reductions are to be admissible at all, this one can be made without fear of error. The specific gravity multiplied by this weight of unit volume of distilled water of the same temperature gives the *density* of the sample water at that temperature, that is, it gives the weight of 1 c.c. of it in grammes. It may also be correctly described as the specific gravity of the water at the temperature, that of distilled water of 4° C. being unity.

"The density at temperature of observation can now at once be reduced to its value at whatever is chosen as common temperature, and at the temperature which it had *in situ*. Naturally, these reduced values are affected by whatever uncertainty attaches to the tables used. For purposes of control, it is well, in an expedition, to preserve very carefully considerable samples of typical waters, and, as opportunity offers, to determine their specific gravity against distilled water at different temperatures. There is no reason to suppose that the precision of these determinations would stand in any way behind that of the observations on which the tables are founded, and as they would have been made on the actual waters which are under consideration, they should have the preference.

"It will be obvious from these remarks how necessary it is, in an expedition, to have a supply of perfectly pure distilled water, to make parallel observations under the conditions on board. Also, as before recommended, typical samples of the waters collected should be kept for careful determination of their density with the same hydrometer at different temperatures, and especially at or near the temperature taken as the common temperature of reduction.

"For observing on board ship, I find that the method used in the *Challenger*, of placing the cylinder on a swinging table, gives better results than any other. In the *Princesse Alice*, a ship of not more than 600 tons, the motion at sea is always considerable, but in ordinary circumstances the maximum amplitude of the motion of the floating hydrometer was not over 3 mm. The vibration period of the hydrometer always interferes with that of the ship and swinging table, producing moments of rest, and my experience is that a moderate rate of motion is an advantage. The individual readings of a

series made under favourable circumstances at sea generally agree more closely with the mean than is the case with a series made under similar circumstances on land. The limit to the amount of motion with which trustworthy observations can be made does not depend on the hydrometer, but on the observer. When the motion goes beyond a certain amount of violence, the observer's attention is entirely taken up in looking after his own stability, and in preventing collision with the swinging table.

"In the *Princesse Alice* I frequently compelled myself to observe when the motion was violent, and then kept the waters for observation under more favourable circumstances. I rarely found any sensible difference in the results; but the labour of making the observations in bad weather is very great, and has an irritating effect. In the *Challenger* there was no difficulty in deciding whether the observations should be proceeded with or not, because there was no difficulty in making them in weather that admitted of the main-deck port, which lighted and ventilated the laboratory, being kept open. When it was shut, the darkness put a stop to such observations independently of the motion.

"It is, perhaps, not wholly unnecessary to point out that to obtain good results with a method such as this the observer must have a certain amount of dexterity and patience, but more particularly he must approach the matter with the desire to succeed. There is never any difficulty in making unsuccessful experiments.

"The following table gives the results of determinations of specific gravities of samples of Mediterranean water collected in 1893 by H.S.H. the Prince of Monaco, which happened to be made at identical

TABLE X.

Water, No.	Hydrometer, No.	Temperature, t° C.	Specific Gravity at t°.	Difference.	Water, No.	Hydrometer, No.	Temperature, t° C.	Specific Gravity at t°.	Difference.
8	6	8·05	1·030156	16	56A	1	10·00	1·029944	0
	1	8·10	140			6	10·05	944	
21	1	8·00	1·030211	15	8A	1	10·00	1·030271	27
	6	8·05	196			16	10·05	244	
56	6	8·00	1·030036	4	52	6	10·00	1·029927	33
	38	8·00	032			1	10·00	894	
51	1	10·00	1·029966	15	20	38	8·00	1·030002	1
	16	10·10	951			1	8·10	001	
28	38	8·30	1·029234	1	20A	6	8·70	1·029945	8
	29	8·30	235			38	8·75	937	

temperatures with different hydrometers. The specific gravities given are each the means of from nine to eleven separate observations on sea water and distilled water at the same time and at the same temperature. The greatest difference between any pair of values is 3·3 in the fifth decimal place, and the individuals of each pair depend on perfectly distinct sets of weighings, and are therefore quite independent.

"It may safely be asserted that, working in this way, the specific gravity of a sea water or similar solution can be determined with a probable error of not more than ± 1 in the fifth decimal place. In a water whose specific gravity is 1·03000, 1 in the fifth decimal place represents $\frac{1}{3000}$ of the whole solid contents; so that by the careful use of the hydrometric method, the salinity to one part in 75,000 ot water, or differences of 1 grain per gallon, can be determined; and it has proved itself of great use in general chemical practice, especially in cases of pollution of streams."

Meteorological Observations and Instruments.

Full instructions for installation of instruments, and for methods of observation and recording, will be supplied with the instruments. It is unnecessary to repeat them here. But there are one or two points, seldom adequately insisted on in meteorological instructions, which may here be recalled.

Thermometers.—With the thermometers of the Expedition there will be supplied information as regards the position of the point of melting ice and as regards the agreement of other parts of the scale with the standard; but it is safe to affirm that no information will be supplied with regard to the *thermal mass* of the thermometers, or the rapidity with which they respond to changes of the temperature of the medium in which they are placed. The Rate of Cooling, or its reciprocal, the *Term of Cooling*, of a thermometer is as important a constant as the position of the ice-point or the length of a degree. The following considerations will show that the want of knowledge of this constant and of its application may, and in point of fact does, frequently introduce error and confusion into meteorological results.

When two unequal masses of the same substance have the same temperature and hang in the same medium, the temperature of which is constant and lower than their own, their temperature will fall at unequal rates. If, being at the same temperature, they are hung in a medium of constant but higher temperature, their tempera-

ture will rise at unequal rates. These unequal masses may be thermometers with similar but unequal bulbs. Under the same conditions they will lose or gain heat at unequal rates. If, at any epoch, they and the air in which they hang are at the same temperature, and the temperature of the air is changed to another, which is kept constant, it is clear that at equal intervals of time from the initial epoch the two thermometers will have and will show different temperatures, although their scales may be without error. Further, in the ordinary course of diurnal variations of temperature these two thermometers will never again show the same temperature except for a moment of time when, in the exigencies of their different rates of cooling and heating, their thermal paths cross.

The importance of self-recording thermometers for supplying a continuous record of the temperature of the air and of its variations is well understood. The form of instrument most commonly used is, on account of its compactness and comparative cheapness, that known as Richard's recorder. It is usual to control its indications by reading a standard mercurial thermometer hung along side of it, and it is a very common practice to make this reading at 9 a.m., when the temperature of the air is changing most rapidly. When the paper is removed, the temperatures taken from the curve traced will be corrected so as to bring them into harmony with the 9 a.m. readings of the mercurial thermometer. Except in the very unlikely case of the mercurial and the recording thermometers having the same rates or terms of cooling, error will be introduced and not eliminated by this proceeding. The temperature of the air is as good as constant for a considerable time at the hour of the diurnal maximum, which is usually about 2 p.m. This is the hour to compare the recorder with the mercurial thermometer.

Again, if the wet and dry bulb thermometers are not exactly equal and similar—and they never can be—their indications are not exactly comparable in air of changing temperature or humidity.

These few remarks will show the practical importance of a knowledge of the rate or term of cooling of every thermometer used in a meteorological observatory, and of the application of it to the correction of observations. They also show the supreme technical importance of making such thermometers according to a perfectly uniform pattern.

When the thermometer was a novelty and philosophers studied its resources and applications in every direction, the importance of this constant was fully recognised, and the application of it to observations was insisted on.

With the prevalent dilettante character of meteorology its existence was forgotten, and its application fell into desuetude.

The subject is dealt with in great detail and quite exhaustively in the works of Newton, Lambert, Leslie, and others. For profound but, at the same time, simple treatment of this interesting subject, the writings of these great men cannot be surpassed.

The method of determining the rate or term of cooling of a thermometer is simplicity itself; indeed, it can be carried out even in a shop, so that we need never buy a thermometer in ignorance of what may be termed its *thermal nimbleness.*

The necessary observations are best made in a dwelling-room of fair size, in which the air remains for at least a considerable time at a constant temperature. The thermometer, which is not attached to any backing, is whirled in the air until it assumes a constant temperature. This is noted as the temperature of the air at the time. The thermometer is then hung up in the middle of the room, and a reading telescope should be set up at a little distance from it, so that its scale can be read without approaching too near. Except in particular cases, as for persons who are short-sighted, the telescope is not absolutely indispensable. The bulb of the thermometer is then warmed in any convenient way, as by the heat of the hand through a fine cloth, to prevent soiling the glass. The temperature of the thermometer should be raised from fifteen to twenty degrees above that of the air. It is then allowed to cool while hanging quite motionless in the air. When its temperature has fallen a few degrees time is taken to the nearest second when the mercury passes a given division. It is then observed as it falls, at regular equal intervals of time. The length of these intervals of time is regulated by the rapidity with which the thermometer cools, and may conveniently be 5, 10, 20, 30, or even 60 seconds. The observations should be continued until the temperature of the thermometer has fallen to about two degrees above that of the air. This should not have changed during the operation. If there has been any sensible variation the observations should be rejected, and the operation should be repeated when there is no variation.

The principle which should find interpretation in the observations is that *in equal intervals of time the bulb of the thermometer loses equal fractions of the heat which it possessed at the beginning of the interval.* Here heat is understood to mean excess of heat, or the heat corresponding to temperatures above that of the medium in which the thermometer is cooling.

If time has been taken when the temperature of the thermometer

is exactly 10° above that of the air, and it is found that in the 1st second it falls to 9°·9, then at the end of the 1st second the heat remaining is only $\frac{99}{100}$ of the initial amount which we may represent by unity, and in the interval it has lost $\frac{1}{100}$ of the amount that it had at the beginning of the interval. If the above principle holds good, it must lose in the 2nd second $\frac{1}{100}$ of the amount which it has at the beginning of that second, and at the end of the 2nd second the heat remaining will be $\frac{99}{100}$ of the amount which was present at the beginning of that second. But the amount present at the beginning of the 2nd second was $\frac{99}{100}$ of the amount present at the beginning of the 1st second, which is represented by unity. Therefore, referred to the amount present at the zero of reckoning as unity, the amount remaining at the end of the 2nd second should be $(\frac{99}{100})^2$. Similarly, during the 3rd second the thermometer loses $\frac{1}{100}$ of the heat which it had at the beginning of that second, and the amount remaining at the end of the 3rd second will obviously be $\frac{99}{100}$ of $(\frac{99}{100})^2$, or $(\frac{99}{100})^3$. Similarly, at the end of the 4th, 5th, 6th, or nth second, the heat remaining will be $(\frac{99}{100})^4, (\frac{99}{100})^5, (\frac{99}{100})^6 \ldots (\frac{99}{100})^n$ of the original amount present at the zero of reckoning represented as unity. It is obvious that if the law holds good, by giving the suitable value to the index n we can at once calculate the proportion of heat which will remain after any number of seconds of cooling; and it is also obvious that so long as the temperature of the medium remains constant, the thermometer can never exactly reach that temperature, although the difference of the temperatures may be made as small as we like by making the duration of cooling sufficiently long.

It has been said that by giving n the suitable value, we can at once find the heat remaining after the lapse of any time. But the computation of high powers of numbers by ordinary arithmetic is very laborious. If, instead of simple arithmetic, we use logarithmic arithmetic, the computation of a high power is as easy and expeditious as the computation of a low one. In the case which we have imagined the constant fraction is $\frac{99}{100}$. Its logarithm is log. 99 − log. 100, that is $1·9956352 - 2 = 0·9956352 - 1$, which is usually written $\bar{1}·9956352$.

This is the logarithm of the first power of $\frac{99}{100}$, which is the heat remaining at the end of the 1st second of cooling. If we multiply $\bar{1}·9956352$ by 2 we have the logarithm of the square of $\frac{99}{100}$, and if we multiply it by 3, 4 . . . n we have the logarithms of the 3rd, 4th . . . nth power of $\frac{99}{100}$, that is, of the heat remaining at the end of the 3rd, 4th . . . nth second. These logarithms differ from each other by the same

amount. Therefore we have the following rule: If the initial excess of the temperature of the thermometer above the temperature of the air is t, and in any interval of time $d\,\theta$ it falls to $(t - d\,t)$, then after any number n of such intervals $(d\,\theta)$ the logarithm of the fraction of excess temperature remaining is $n \log. \left(\frac{t - d\,t}{t}\right)$; and by multiplying the number corresponding to this logarithm by t, the excess of temperature of the thermometer after n intervals of time, each equal to $d\,\theta$, is given.

The law which has just been explained is Newton's law of cooling, often called the logarithmic law. It is worthy of remark that Newton looked upon this law as axiomatic and self-evident the moment it is stated, and he did not think that it required experimental demonstration. It did not escape question, notably by Amontons; and Lambert, in vindication of Newton, although he had held that the law was self-evident, carried out a beautiful series of experiments, which are detailed at length in the third part of his classical work on Pyrometry* and the measurement of heat. They completely bore out Newton's law.

The method of making the experiment has just been described, and as it is important that every one should be familiar with the practice of it, we give an actual example. (See Table XI.)

The experiment here recorded was made under very favourable circumstances in the month of September in a large room the temperature of which was sensibly the same as that of the air outside, namely 20°·2 C., and this remained quite constant for a much longer time than was required for the experiment; indeed, it hardly varied at all during the day. The results are instructive, because they give a good idea of the kind of agreement between observation and theory which we have a right to expect. The temperature was observed at every ten seconds. The initial excess of the temperature of the thermometer over that of the air is 8·0°, and log. 8·0 = 0·9031. After the first interval of cooling the excess is 6·8°, and log. 6·8 is 0·8325. Taking the initial excess as unity, the fractional excess, or the heat remaining after the first interval of ten seconds, is $\frac{6 \cdot 8}{8 \cdot 0}$, and its logarithm is $0 \cdot 8325 - 0 \cdot 9031 = \bar{1} \cdot 9294 = \log.\ y_1$. After the second interval of ten seconds the excess is 5·8, and log. 5·8 = 0·7634. The fractional excess after the second interval is $\frac{5 \cdot 8}{8 \cdot 0}$, and its logarithm is $0 \cdot 7634 - 0 \cdot 9031 = \bar{1} \cdot 8603$.

* 'Pyrometrie oder vom Maasse des Feuers und der Wärme,' von Johann Heinrich Lambert. 4to. Berlin, 1779.

According to the theory which has been explained above, if the thermometer in cooling loses in each equal interval of time exactly the same fraction of the excess heat which it held at the beginning of the interval, and if the observations are without error, then the logarithms of the fractional excess after the second interval ought to be $2 \times \bar{1}\cdot9294 = \bar{1}\cdot8588$ in place of $\bar{1}\cdot8603$, as above. The difference is obviously not great. In order to know what it amounts to in the observation of the temperature we have $\bar{1}\cdot8588 + 0\cdot9031 = 0\cdot7619 = 5\cdot78°$, which ought to be the excess of the temperature of the thermometer over that of the air, if the thermometer follows the

TABLE XI.

Number of Experiment.	Epoch.	Temperature of Thermometer.	Difference between Temperature of Thermometer and that of Air.	Logarithm of this difference.	Logarithm of quotient of difference by initial difference.	Difference of these Logarithms	Logarithm of quotients calculated for Mean value, $dl = 0\cdot0669$.	Logarithm of calculated difference of Temperature.	Calculated Difference.
n	secs.	t	$t - 20\cdot2 = s.$	$\log s.$	$\log s - 0\cdot9031 = \log y.$	$\log y_n - \log y_{n+1} = dl.$	$\log 1 - n(0\cdot0669) = \log y_c.$	$\log y_c + \log 8 = \log s_c.$	$s_c.$
		°	°						°
0	0	28·2	8·0	0·9031	0	0·0706	0·0000	0·9031	8·00
1	10	27·0	6·8	0·8325	$\bar{1}\cdot9294$	·0691	$\bar{1}\cdot9331$	0·8362	6·86
2	20	26·0	5·8	0·7634	$\bar{1}\cdot8603$	·0644	$\bar{1}\cdot8662$	0·7693	5·88
3	30	25·2	5·0	0·6990	$\bar{1}\cdot7959$	·0706	$\bar{1}\cdot7993$	0·7024	5·04
4	40	24·45	4·25	0·6284	$\bar{1}\cdot7253$	·0661	$\bar{1}\cdot7324$	0·6355	4·32
5	50	23·85	3·65	0·5623	$\bar{1}\cdot6592$	·0709	$\bar{1}\cdot6655$	0·5686	3·70
6	60	23·3	3·1	0·4914	$\bar{1}\cdot5883$	·0582	$\bar{1}\cdot5986$	0·5017	3·17
7	70	22·85	2·65	0·4232	$\bar{1}\cdot5301$	·0715	$\bar{1}\cdot5317$	0·4348	2·72
8	80	22·5	2·3	0·3617	$\bar{1}\cdot4586$	·0607	$\bar{1}\cdot4648$	0·3679	2·33
9	90	22·2	2·0	0·3010	$\bar{1}\cdot3979$	..	$\bar{1}\cdot3979$	0·3010	2·00

law and if the first two observations are exact. The agreement with the observed difference, 5·80°, is quite satisfactory. But we know that no observations are free from error, which must affect the first observations as well as the others. In the table we have the observations made at the end of each of nine consecutive intervals of ten seconds. In the seventh column of the table we have the differences of the consecutive logarithms of the fractional excesses remaining. Theoretically these differences ought to be identical. They are not; and their variations are irregular. We may therefore take the mean difference, which is 0·0669, and with it calculate what ought to be

the excess remaining after each interval of ten seconds. The initial fractional excess, y_0, is 1, and its logarithm is 0. Subtracting $0 \cdot 0669$ we get $\bar{1} \cdot 9331 = \log. y_1$; and again subtracting $0 \cdot 0669$ we get $\bar{1} \cdot 8662 = \log. y_2$; and so on. The logarithms obtained are found in the eighth column of the table. In the ninth column we have the sum of log. 8·0, or 0·9031, and the respective numbers in the eighth column. They are the logarithms of the calculated thermometric excesses. These are given in the tenth column.

The first and the last entries in this column necessarily agree with the observed values in the fourth column. The greatest difference is 0·08°, so that the actual rate of cooling may be held to agree fairly well with the rate which, according to theory, we ought to observe if the bulb of the thermometer were a perfectly homogeneous body of infinite thermal conductivity and of symmetrical shape, cooling in a vacuum enclosed by walls having a definite and constant temperature. We know that this description fits neither the thermometer nor the room in which it was cooling. The shape of the bulb, whether it be cylindrical or spherical, is not symmetrical in the above sense, because, for purposes of observation, the thermometer must always have a stem, and the part of the bulb where it is united to the stem is exposed to different conditions, as regards cooling, from the other parts of it. Although the thermal conductivity of the bulb of a mercurial thermometer is not perfect, its degree of imperfection is not such as to introduce much error into observations of this kind. The temperature of the room, and no doubt that of its walls, was very constant, but of course there was no vacuum.

The instrumental deformity introduced by the necessity of a stem for the thermometer must always introduce some deviation from the normal rate of cooling, but it is, as thermometers are made, not practically of much importance. The disturbing element which takes precedence of all others is the air.

The conditions in which the experiments quoted in the table were made were as favourable as they could be, and it would not be possible to get air more motionless than it was. But however motionless the mass of the air may be, a thermometer, or any other object, suspended in it, and having a higher temperature, must produce convection currents in its immediate neighbourhood, which will be the more energetic the greater the difference of temperature. Hence the conditions under which a thermometer cools in air are complex. In the first place it cools by radiation to its surroundings, and, setting aside instrumental imperfections, this takes place independently, as it would in a vacuum, according to the logarithmic law, losing

equal fractions of heat in equal times. In the second place it loses heat by contact with the air, and the rate at which this loss takes place depends on the rate of renewal of successive envelopes of fresh air, and this diminishes as the temperature of the thermometer approaches to that of the air in which it is cooling. This explains why the term of cooling when the thermometer is only one or two degrees warmer than the air is greater than when it is five to fifteen degrees warmer. If differences of temperature amounting to 10° or 15° C. are used, the terms of cooling found are very concordant.

In the case detailed in the Table XI., p. 127, the observations were made at equal intervals of ten seconds, and the mean logarithmic difference (dl) was found to be 0·0669, and the logarithm of the fraction remaining after the lapse of the first interval (log. y_1) was $\bar{1}$·9331, whence $y_1 = 0{\cdot}8572$. Now the fraction $\frac{6}{7}$ is expressed by the circulating decimal $0{\cdot}\dot{8}5714\dot{2}$, therefore $y_1 = \frac{6}{7}$, and in each interval of ten seconds the loss of heat is $\frac{1}{7}$ of the amount which was present at the beginning of it. Therefore, if in each succeeding interval of ten seconds the same *amount* of heat were lost, the whole of the excess of heat would disappear in seven such intervals, or in seventy seconds. Therefore, the arithmetical result which we arrive at from observations made at intervals of ten seconds is that the *term of cooling* of the thermometer is seventy seconds.

But if 0·0669 is the logarithmic difference for ten seconds, then 0·00669 is the logarithmic difference for one second, 0·000669 for one-tenth of a second, 0·0000669 for one-hundredth of a second, and so on. The resulting terms of cooling derived from these different intervals and logarithmic differences, and the method of arriving at them, will be apparent from the following table:

TABLE XII.

Length of interval (seconds) . . $d\theta$	10	1	0·1	0·01
Logarithmic difference . . . . . dl	0·0669	0·00669	0·000669	0·0000669
Log. first fractional excess . log. y_1	$\bar{1}$·9331	$\bar{1}$·99331	$\bar{1}$·999331	$\bar{1}$·9999331
Fraction remaining at end of first interval . . . . y_1	0·8572	0·984714	0·99846	0·999846
Fraction lost in first interval . $1 - y_1$	0·1428	0·015286	0·00154	0·000154
Reciprocal of fraction lost . . $\frac{1}{1 - y_1}$	7	65·4193	649·35	6493·5
Term of cooling, in secs., $d\theta \frac{1}{1-y} = R$	70	65·4	64·9	64·9

The rule * for finding the term of cooling referred to the shortest possible intervals of time, and the smallest logarithmic differences, from observed values of $d\,\theta$ and $d\,l$ is: *Divide the modulus of the system of logarithms,* 0·434295 *by the logarithmic difference $d\,l$, and multiply the quotient by the interval of time $d\,\theta$. The product is the term of cooling expressed in the same units of time that have been used in expressing the time interval $d\,\theta$.*

For the above case we have for the true term of cooling—

$$\mathrm{R} = \frac{0 \cdot 434295}{0 \cdot 0669} \times 10 = 64 \cdot 917 \text{ seconds.}$$

In the application of this rule we may make the interval anything we please. We may, therefore, choose it so that the loss of heat during it is expressed by a simple fraction, such as one-half. The convenience of this method was first pointed out by Leslie, and it affords by far the best practical method. It is sufficient, for instance, to heat the thermometer to 10° or 11° above the temperature of the atmosphere, take time when it is exactly 8° warmer than the air, and again when its temperature has fallen to 4° above that of the air. The excess heat present at the beginning of the interval is 1, and that at the end of the interval is ½. Then we have—

$$d\,l = \log.\ 1 - \log.\ \tfrac{1}{2} = 0 \cdot 30103;$$

and the term of cooling is

$$\mathrm{R} = \frac{0 \cdot 434295}{0 \cdot 30103}\, d\,\theta;$$

or, very approximately, $\mathrm{R} = \dfrac{101}{70}\, d\,\theta$.

Hence the rule to find the term of cooling when the time in which one-half of the heat excess is lost is: *Multiply that interval $d\,\theta$ by* 101 *and divide it by* 70. *The quotient is the term of cooling.*

It is evident that there is no difficulty in making this observation in a shop, and the time in which the instrument loses half its heat is sufficient without further computation to give a good idea of what has been called its *thermal nimbleness.* The want of a term commonly used to express this important property shows how much the property itself has been neglected.

Table XIII. gives an example of the use of the method of the "half-fall" in the case of a thermometer, first with its bulb plain, and secondly with its bulb silvered.

* 'Experimental Inquiry into the Nature of Heat,' by John Leslie. Edinburgh, 1804. Page 265.

It will be seen that silvering the bulb has in this case increased the term of cooling in the proportion of about 3 to 4, and the rate of cooling is diminished in the inverse proportion. Also for initial excesses of temperature between 16° and 6° the terms of cooling are very concordant. In both cases they increase when the temperature excess falls to 4°. It is to be observed that not only is the effect of convection less powerful at low temperatures, but any slight change in the temperature of the air makes itself more felt when the difference between it and that of the thermometer is small, than when it is great.

TABLE XIII.

Bulb Plain.			Excess of Temperature.	Bulb Silvered.		
Term of Cooling.	Time in which half the excess is lost.	Epoch.		Epoch.	Time in which half the excess is lost.	Term of Cooling.
secs.	secs.	secs.	°C.	secs.	secs.	secs.
157	109	0	16	0	137	198
156	108	20	14	23·5	143·5	207
157	109	45	12	54	144	208
157	109	75	10	92	144	208
141	98	109	8	137	146	211
		128	7	167		
162	112	154	6	198	145	209
		184	5	236		
180	125	207	4	283	150	216
		266	3	343		
		332	2	433		

The Use of the Thermometer for Measuring the Velocity of Weak Currents of Air.—The difference between motionless air in a room and calm air outside is best shown and is accurately measured by the difference between the terms of cooling of the same thermometer as determined in the one medium and then in the other. This difference is due to the fact that calm air outside is not motionless, while in a room of constant temperature it is practically so. It is evident that if the difference is caused by the motion of the air, then that difference must also be a measure of the motion. As has been pointed out above, this was perceived by Leslie, and he gives formulæ * for calculating the velocity of the wind from the reduction of the term of cooling of a tin vessel holding about half a litre of water.

* Loc. cit., p. 283.

If R be the term of cooling in still air, or the *fundamental* term of cooling, and r be the *occasional* term of cooling when the air is moving with any velocity v, then Leslie gives the following expressions for this velocity:

$$v = \frac{20}{3} \cdot \frac{R - r}{r} \text{ in feet per second;}$$

or, $$v = 4\tfrac{1}{2} \frac{R - r}{r} \text{ in miles per hour.}$$

Converting into metrical units, we have

$$v = 2 \cdot 032 \frac{R - r}{r} \text{ in metres per second.}$$

It is right to observe that R in Leslie's equations is the term of cooling of his flask of water when suspended "*out of doors, on a calm evening.*"

Difference between a Calm Indoors and a Calm Out-of-Doors.— The preceding equations give the diminution of the term of cooling produced by sensible wind as compared with a calm, both being out-of-doors. It does not appear that Leslie distinguished between a calm indoors and a calm out-of-doors.

Returning to Table XI. at page 127, we find the term of cooling of the thermometer to be in round numbers 65 seconds in the still air of a room. A number of observations were made with the same instrument in the open air in very calm fine weather. The method of the "half-fall" as exemplified in Table XIII. was used, the excesses of temperature used being 12°, 10°, 8° and 6° C. The experiments were made in Edinburgh on September 16, 1894, during very fine anticyclonic weather. All the afternoon the air was perfectly calm. The smoke from chimneys went straight up and indicated no horizontal component of motion.

In the following table the "half-falls" for different initial excesses at different times during the afternoon are given, which show the extent of their agreement. The mean "half-fall" is then converted into the term of cooling by multiplying by $\frac{101}{70}$.

This table shows well what great differences may exist in the calmness of calm air. Nobody doubts that such motions do occur; otherwise it would be impossible for the permanent difference of temperature which is found generally to exist at different elevations in the atmosphere to be maintained; and it is interesting to have a means of gauging them.

In order to obtain a standard of measurement, a number of

observations were made by moving the thermometer at different velocities in the air of the room, and observing the rates of cooling. Dealing only with low velocities it was found that while in perfectly still air the term was 65 seconds; when moving through the air at the rate of 2 m. per second the term was 17·2 seconds; and when the velocity was 1 m. per second it was 24·6 m. per second; while at 0·5 m. per second the term was 30 seconds. Allowing that, whether moved or not, the cooling of the thermometer goes on independently at the still-air rate of $\frac{1}{65}$ per second, and subtracting this from the reciprocals of the above numbers, we have the rates of cooling due to motion of the air;—at the rate of 2 m. $\frac{1}{24}$, of 1 m. $\frac{1}{40}$, and of $\frac{1}{2}$ m. per second $\frac{1}{56}$, the rate of cooling in calm air being $\frac{1}{65}$. The reciprocals of these fractions, or the terms, are 24, 40, 56 and 65, which are in the proportion 3 : 5 : 7 : 8.

TABLE XIV.

Excess.	Time P.M.				
	12.45	1·10	1.40	2.10	6.30
	Duration of Half-fall in Seconds.				
12° C.	26	..	33	22	36
10° C.	25	..	36	22	36
8° C.	27	31	36	25	35
6° C.	27	31	30	31	33
Mean	26·25	31	33·75	25	35
Term	37·9	44·7	48·7	36·0	50·5

The importance of these figures is that they show that thermometers in the open air, even when the air appears to be calm, are in reality well ventilated. In a room, the temperature of the dry bulb, and still more that of the wet bulb, are very imperfectly given by a stationary thermometer; both thermometers must be whirled in order to get anything like exact observations. In the thermometer screens of a meteorological station the instruments are certainly well ventilated when there is a wind; and we see that, even in a calm, the ventilation may be sufficient.

The Thermometer as a Calorimeter.—The term of cooling of a thermometer and the method of its determination have been dwelt on at considerable length, because the information regarding it to be found in manuals is usually defective. The same remark applies to

the *thermal mass* of the bulb of the thermometer and the method of determining it. *When we have these two constants, namely, the term of cooling and the thermal mass, the thermometer becomes a calorimeter, and its radius of research is much increased.*

The thermal mass of the bulb of a thermometer is completely specified if we know (*a*) the weight of mercury which it contains; (*b*) the weight of the glass which forms the envelope; (*c*) the specific heat of mercury; and (*d*) the specific heat of the particular glass used. As the mercury used for thermometers must be perfectly pure, *c* is known. Many different kinds of glass are used, and the information regarding their specific heat is very defective. This constant should therefore be determined for the particular sample of glass used in the construction of the thermometers. By working in association with the thermometer maker there is no difficulty in ascertaining the exact weight of mercury in the thermometer, or that of the glass which goes to the bulb. Then if we multiply the weights of these substances used by their respective specific heats, the sum of the products is the thermal mass of the bulb expressed as the weight, in grammes, of water, which is thermally equivalent to it. This constant is usually, and conveniently, called the *water value.* Calorimetry is an important department of physics and physical chemistry, and the methods of determining water values are given in all treatises on the subject. Where the size of the thermometer is considerable the specific heat of its bulb can be determined directly by the old "method of mixtures," the thermometer itself being one party to the mixture. As the term of cooling of a thermometer increases in proportion to the size of the bulb, it is clear that thermometers intended for meteorological use should have as small bulbs as possible, and the method of mixtures is not applicable for the determination of their thermal masses. Again, it is out of the question to expect these thermometers to be constructed so that the respective weights of mercury and of glass in their bulbs shall be accurately known. The following method of determining this constant is very convenient. It depends on mensuration, and was published by the writer in 1894.*

Estimation of the Thermal Mass of the Bulb of a Thermometer by Mensuration.—The method is shortly stated in the following Rule: *Determine the external volume or displacement of the bulb in cubic centimetres; multiply it by* 0·475, *and the product is the water value of the*

* 'On Rapid Variations of Atmospheric Temperature, especially during *Föhn*, and the methods of observing them,' by J. Y. Buchanan, F.R.S. *Proc. R. S.* (1894), vol. lvi. p. 126.

bulb in grammes. The factor 0·475 which occurs in this rule is arrived at as follows: The density of mercury is 13·596, and its specific heat is 0·033, therefore the capacity for heat of 1 c.c. is the same as that of 0·4486 grm. of water. The density of ordinary glass may be taken at 2·6 and its specific heat at 0·198, whence the capacity for heat of 1 c.c. of glass is the same as that of 0·5148 grm. water. Therefore when referred to unit volume the specific heats of these two bodies are very nearly identical, and if we have the total volume and apply the mean of the above values, the result will be a very close approximation to the water value of the bulb, quite independently of the exact proportion in which the mercury and the glass enter into its construction. Suppose that the displacement of the bulb were 1 c.c. and that the glass were infinitely thin, so that the bulb were all mercury, then its water value would be 0·4486 grm. If, on the other hand, the internal volume of the bulb were infinitely small, so that it consisted entirely of glass, its water value would be 0·5148 grm. But the bulbs of thermometers of most ordinary patterns are very much alike in construction. It is not usual in the construction of even the best instruments to take into account the amount of mercury or of glass present in the bulb. Such data are available only in the case of thermometers especially constructed for use in calorimeters. As they are themselves parts of the calorimeter, their heat constants must be ascertained; and, as was pointed out above, this is most easily and most accurately done during their construction. Berthelot* gives the thermal constants of three thermometers which were determined during construction. These are embodied in columns 1, 2 and 3 of the following table. Column 4 refers to a thermometer belonging to the writer; it is by Chabaud, of Paris, and is constructed for use with Berthelot's calorimeter. The data have been ascertained during construction, and are engraved upon the stem.

In the following table the numerical data in the first part are taken from 'Berthelot's Mechanique Chimique,' pp. 162, 167.

In this table the fundamental gravimetric data are—*b* the weight of mercury and *d* the weight of glass in the bulb—both of which are furnished by the makers, whose names are given in line *a*. In columns 1, 2 and 3 the water values of the mercury and the glass, *c* and *e*, are given by Berthelot. In column 4 they were calculated, using 0·033 as the specific heat of mercury and 0·198 as that of glass, and the constant sought and arrived at in this part of the table is *f*, the water value of the bulb as a whole. The second part of the

* 'Essai de Mechanique chimique, fondeé sur la Thermochimie,' par M. Berthelot. Membre de l'Institut, Paris. Dunod, 1879.

table is based on the same gravimetric data, namely the weight of mercury and of glass (*b* and *d*). From these the volumes are calculated, taking 13·596 as the density of mercury and 2·6 as that of glass, and they are given in lines *g* and *i* respectively. When the specific heat of a body is spoken of without further qualification, the water value of 1 grm. of the substance is meant. When we are dealing with volumes, we require to know the specific heat per unit volume, and that is the water value of 1 c.c. of the substance.

TABLE XV.—CALORIMETRIC SPECIFICATION OF THERMOMETERS.

Computation of the Water Value of the Bulb from Data supplied by the Maker.

Maker of thermometer	*a*	Fastré	Baudin	Tonnelot	Chabaud
Weight of mercury, grms.	*b*	18·003	30·20	3·781	25·09
Water value of mercury, grms. . . .	*c*	0·60	1·01	0·126	0·828
Weight of glass, grms.	*d*	3·075	2·43	0·599	2·58
Water value of mercury, grms. . . .	*e*	0·61	0·49	0·120	0·511
Water value of bulb, grms. . $c+e=$	*f*	1·21	1·50	0·246	1·339

Calculation of Water Value of Bulb and of its Specific Heat per Unit Volume.

Volume of mercury, c.c. . $\frac{b}{13\cdot596}=$	*g*	1·37	2·221	0·278	1·845
Water value of mercury, grms. $0\cdot4486g=$	*h*	0·615	0·996	0·125	0·828
Volume of glass, c.c. . . . . $\frac{d}{2\cdot6}=$	*i*	1·18	0·935	0·230	0·990
Water value of glass, grms. $0\cdot5148i=$	*k*	0·607	0·481	0·118	0·510
Water value of bulb, grms. . . $h+k=$	*l*	1·222	1·477	0·243	1·338
Total volume of bulb, c.c. . . . $g+i=$	*m*	2·55	3·156	0·508	2·835
Specific heat of bulb per unit vol. $\frac{l}{m}=$	*n*	0·474	0·475	0·484	0·472

Centesimal Composition of the Bulb by Volume.

Mercury volumes per cent.	..	53·75	70·3	54·7	65·1
Glass volumes per cent.	..	46·25	29·7	45·3	34·9

Now the density of a substance, when the metrical system is used, is the weight of 1 c.c., therefore the weight of 1 c.c. of mercury is 13·596 grms. and that of the same volume of glass is 2·6 grms. Multiplying 13·596 by 0·033, the specific heat of mercury, we obtain 0·4486, which is the water value of 1 c.c. mercury, or its specific heat per unit volume. Multiplying 2·6 by 0·198, we obtain 0·5148 as the specific heat per unit volume of glass. If now we multiply the volume of mercury, *g*, by 0·4486 and the volume of glass, *i*, by 0·5148, we obtain *h* and *k*, the water values of the

volumes of mercury and of glass respectively. The sum of these, l, is the water value of the bulb as a whole. If the values of l be compared with those of f in the first part of the table, the agreement will be found to be very close. With regard to the mercury, there is not room for much discrepancy, because it is an elementary body, and it can be used in the construction of thermometers only when it is in a state of purity. It is otherwise with the glass. Neither Berthelot nor the makers give its composition, its density, or its specific heat. Although the composition of the glass is of great importance, a knowledge of it is not necessary for thermometric or calorimetric purposes; on the other hand, a knowledge of both the density and the specific heat of the glass is essential. Yet it is very rarely furnished. The values used in the table are commonly occurring ones; and the agreement in the water values of the glass arrived at in the first and second parts of the table, lines e and k, shows that they apply to the glass used. Having obtained the total volume of the bulb, m, and its water value l, we obtain at once $\frac{l}{m} = n$, the specific heat per unit volume of the bulb considered as a whole, or in other words it is the water value of 1 c.c. of bulb. The values of n agree very closely, the extremes being 0·484 and 0·472, and the mean 0·476. The factor used in the rule, page 134, is 0·475, which is a more convenient number than 0·476, and it has now been shown how it is arrived at.

The third part of the table gives the centesimal composition by volume of the bulbs of the four thermometers. The thermometers are by different makers, and the quantity of mercury in each shows how different they must be in pattern; yet there is great resemblance in their composition by volume. The mean composition is 61 volumes of mercury to 39 volumes of glass, and *we shall never be far wrong if we take the volumes of the mercury and glass in a thermometer bulb to be in the proportion* 3 : 2.

Method of Determining the External Volume or Displacement of the Bulb.—We have shown how the factor 0·475 is arrived at; it now remains to show how the volume or displacement of the bulb is determined. It can be roughly ascertained by actual displacement of water in a graduated vessel, but this method is not sufficiently delicate. When the thermometer has a spherical bulb, its diameter must be measured with calipers. The result is not usually satisfactory, because the length to be measured is very short, and it is never certain that the bulb is truly spherical. Fortunately it is usual nowadays to make thermometers with cylindrical bulbs, and their

volume is easily measured. Instead of using calipers a fine thread is wound ten, twenty, thirty or more times round the bulb, then unwound and its length measured; this divided by the number of turns gives the circumference of the cylinder. The length of the cylinder is then measured, and its ends are assumed to be hemispherical. With the circumference thus determined, the diameter and sectional area are calculated, or, more conveniently, taken from tables. The length of the cylinder multiplied by the sectional area gives the volume of the cylindrical portion. The two hemispherical ends make up a sphere of the same diameter as that of the cylinder, and its volume is likewise calculated, or taken from tables. It is added to that of the cylinder, and the sum is the volume or displacement of the bulb. It is convenient to record the measurements in terms of the centimetre, and the volume is then given in cubic centimetres. The external cooling surface of the bulb is found by adding the hemispherical surface of the exposed end to the cylindrical surface, which is the product of the length of the cylinder into its circumference. The area of the external surface is given in square centimetres (cm.^{2}). It is important to observe that, when cooling, a thermometer loses heat through the whole area of its external surface; when receiving heat from a particular direction, as for instance, from the sun, the receiving area is, for the cylindrical part of the bulb, its length multiplied by its diameter, and for the hemispherical ends the area of a great circle of the sphere.

All these measurements have been carefully made on the bulb of the thermometer by Chabaud, col. 4, Table XV. For the determination of the circumference, a fine thread was wound forty times round the cylindrical part. When unwound it measured 111 cm., whence we have:

Circumference		2·775 cm.
Diameter		0·883 cm.
Circular area of cylinder		0·6124 cm^2.
Length of cylinder		4·08 cm.
Volume of cylinder	4·08 × 0·6124 =	2·498 cc.
Volume of sphere 0·883 cm. in diameter		0·377 cc.
Whence total volume of bulb		2·875 cc.
Water value of bulb	0·475 × 2·875 =	1·366 grms.

It will be seen that by mensuration we arrive at 2·875 cc. as the volume of the bulb in place of 2·835 cc. as derived from the weights supplied by the maker. The difference, 0·04 cc., is under 1½ per cent. of the whole volume. Applying 0·475 as the specific heat per unit volume of the bulb, we obtain for the water value 1·366 in place of 1·338 grs., a difference of 0·028, which is just 2 per cent.

The agreement is quite satisfactory, and we can therefore use this method with perfect confidence in determining the water value of the bulbs of all our thermometers.

The area of the external cylindrical surface is $4 \cdot 08 \times 2 \cdot 775$	$= 11 \cdot 322$ cm².
Surface of one hemisphere	$= 1 \cdot 225$ cm².
Whence the total external surface	$= 12 \cdot 547$ cm².

The area of this surface is the area of the *outlet* for heat, and, other things being equal, it determines the rate and term of cooling. We found the total volume of the bulb to be 2·875 cc., and its water value 1·366 grs. It is clear that, if the area of the external surface remains constant and the volume or the water value is increased, other things remaining the same, the term of cooling will be increased and, of course, the rate diminished. It is quite analogous to the case of a water-cistern. If the area of outlet remains the same the time which it will take for the cistern to empty itself will depend on the quantity of water in it, while, if the size of the cistern and the quantity of water in it remain the same, the time which it will take to empty itself will depend on the *smallness* of the outlet. Other things being equal, the term of cooling of a thermometer will depend on the magnitude of the ratio, volume of bulb : area of external surface.

In this case the ratio is 12·547 : 2·875 = 4·364. This may be called the *virtual cooling radius*. In the case of a cooling sphere it is the radius of the sphere.

The physical and thermal data relating to particular thermometers have been dwelt upon at great length because they convey a much better idea of the nature and propagation of heat than more voluminous general statements. It may be well here to remind the reader that in the department of science which has been called *geo-physics*, when it is a question of specific heat it is nearly always specific heat per unit volume that is required, and the thermal study of thermometers is helpful from this point of view.

Calorimetric Constants of a Thermograph.—It was interesting to know what could be obtained with a recording thermometer of ordinary type, and in Table XVI. the results of some observations made in Cambridge with a Richard's recorder are given.

The figures in this table are taken from the curves drawn by the instrument on a drum revolving once in forty-eight minutes. The instrument was allowed to take the temperature of the room, then exposed in the shade in the open air when a fresh breeze was blowing, and allowed to remain there until it had taken the temperature of the air. It was then transferred to the room, and allowed to rise until it attained its temperature.

In this way two sets of curves were obtained, consisting of three curves in still air and three in a fresh breeze. The results are not very concordant, for, although the scale of time is very open—one minute occupying 5 mm.—the temperature scale was very close, 1° occupying only 1 mm. The object, however, of the table is to show what can be expected from an instrument of the kind in the measurement of changes of temperature. The results obtained in the open air would necessarily vary somewhat, because, although a fresh breeze was blowing all the time, a fresh breeze varies in velocity.

In order to obtain the best results from a thermometer, it should be exposed to uniform ventilation. This can only be effected by

TABLE XVI., GIVING THE TIME IN SECONDS REQUIRED BY A RICHARD'S RECORDING THERMOMETER TO CHANGE ITS TEMPERATURE BY 1° C. FOR A GIVEN DIFFERENCE OF TEMPERATURE BETWEEN IT AND THE AIR.

Difference of temperature between thermometer and air at beginning of exposure.		12°.	11°.	10°.	9°.	8°.	7°.	6°.	5°.	4°.	3°.	2°.
Time in seconds required by thermometer to fall or rise 1° C. for above differences.	In the open air and fresh breezes.	20"	20"	25"	25"	30"	30"	30"	65"	90"	90"	240"
		..	..	..	..	..	35	45	120	130	150	300
		..	..	..	..	..	20	35	40	45	80	240
	Mean from curve.	20	22	24	26	28	30	35	52	84	140	250
	In still air in a room.	..	..	..	..	..	..	60	70	110	130	210
		..	..	..	..	..	..	..	90	100	300	450
		..	..	..	..	..	..	..	..	120	160	300
	Mean .	..	..	..	..	..	..	60	80	110	180	320

artificial means, and they necessarily tend to efface sharp variations of temperature.

Departing from the mercurial thermometer the writer has found the simple air thermometer very good for indicating and measuring quick variations of temperature. It has the advantage of lightness and cheapness. The form which I use is a glass bulb, of about 3 cm. diameter on a straight stem of about 10 cm. length. This can be attached to a U-tube of greater or less diameter, according as the differences of temperature to be observed are great or small. The U-tube has some coloured water as indicator, and the indications of the instrument are compared with those of a thermometer. As the instrument is only put together when it is wanted, the variations of

barometric pressure do not affect it. It has the great advantage that it can be connected with a *tambour*, and thus be made to record. The sensitiveness of the glass air thermometer is about the same as that of a very fine mercurial thermometer made for me by Messrs. Hicks. The air thermometer, however, would be more sensitive if the ball were made of thin metal instead of glass.

Air thermometers of this simple kind described, are very easily made so as to give calorimetrical results. It is only necessary to weigh and measure the piece of glass tube before and after blowing the bulb. The shortening of the straight part of the tube after blowing gives the length of it which has been expanded into a ball, and from

TABLE XVII.—PARTICULARS OF CALORIMETRIC AIR THERMOMETERS MADE OF LEAD GLASS.

Number of Instrument.	1.	2.	3.	4.	5.
Original weight of tube (grm.)	7·724	18·508	18·4186	18·8136	18·6169
„ length of tube (mm.) .	225·7	193·0	192·1	196·0	194·25
Ditto after blowing	197·0	144·0	137·0	126·4	104·0
Difference	28·7	49·0	55·1	70·4	90·25
Weight of 10 mm. tube (grm.) .	0·7853	0·9590	0·9590	0·9580	0·9580
Weight of bulb (grm.) . . .	2·2538	4·6991	5·2841	6·7443	8·6550
Diameter of bulb (mm.) . .	24	32	38	45	51
Volume of ditto (cc.) . . .	7·238	17·157	28·731	47·713	69·456
Surface of bulb (sq. c.m.) . .	18·095	32·170	45·364	63·617	81·713
Volume of glass at sp. gr. = 3.0	0·7513	1·5664	1·7614	2·2481	2·8850
Thickness of glass (mm.) . .	0·415	0·487	0·388	0·353	0·353
Water value of bulb, sp. heat = 0·57	0·4282	0·8928	1·0040	1·2814	1·6445
Surface + water value . . .	42·26	36·03	45·18	37·25	42·24

the known length and weight of the original piece of tube, the weight of the bulb is found. By carefully gauging the diameter of the ball its surface can be obtained, and from that the thickness of the glass. When the specific heat of the glass is known, the water value of the bulb is given; if the air contained is taken into account, the value is increased by from 1 to 2 per cent. The surface of the ball divided by the water value gives an expression for the sensitiveness of the instrument.

In Table XVII. the particulars of several air thermometers are given. As they are made of lead glass, both the density and the

capacity for heat per unit of weight are higher than in the case of ordinary German glass, but the specific heat per unit of volume is probably very little affected.

Calorimetric Constants of Deep-sea Thermometers.—It is evident that a knowledge of the calorimetric constants of the deep-sea thermometer is necessary, if we are to have the conviction that the temperature indicated by it is in truth the temperature of the water in which it was immersed. This is all the more necessary because, in order to guard the bulb of the thermometer against the squeezing effect of the pressure of the column of water to which it is exposed when in use, it is hermetically enclosed in an outside bulb, the space between them being partially filled with mercury. This extra bulb increases greatly the term of cooling of the thermometer. The conditions are quite analogous to those regulating the cooling of thermometers in air. The term is comparatively long when the thermometer is immersed in still water and kept motionless in it. When the water has relative motion with regard to the thermometer the term is reduced in proportion to that motion.

For practical purposes we require to know how long we must leave the thermometer at the particular depth in order to be sure that it has taken the temperature of the water. The experiments required in order to furnish this knowledge are extremely simple. The principle is exactly the same as that which governs the behaviour of thermometers in air. The thermometer loses equal fractions of its excessive heat in equal intervals of time. These intervals are very much shorter when the instrument is immersed in water than when it is in air. When the difference of temperature is at all considerable the thermometer falls very rapidly at first, and more slowly as it approaches to the temperature of the water. The divisions of the scale of a thermometer ought to be about one millimetre apart. If in reading the thermometer we estimate tenths of this amount, then it is important to know how long the thermometer takes to assume the temperature of the water within one-tenth of one of its own divisions. If we estimate only to one-half of a division, then it is sufficient to know how long the thermometer takes to arrive at that of the water within one-half of one of its own divisions. It does not matter what the thermometric value of each division is. The following imaginary case will illustrate this. It is assumed that when immersed in still water the thermometer loses half its excessive heat in twenty seconds. When immersed in the water the excessive temperature of the thermometer is represented by 4·8 of its own divisions.

Thus we should have—

Excess temperature, divisions .	4·8	2·4	1·2	0·6	0·3	0·15	0·075
Time elapsed, seconds . . .	0	20	40	60	80	100	120

In this imaginary case the temperature of the thermometer will have attained that of the water in 120 seconds, or two minutes.

When the water touching the thermometer is moving, whether the water runs past the thermometer or the thermometer runs through the water, then the time which the thermometer requires to lose its excessive heat is very much shorter. In actual sounding practice the thermometer arrives at the depth at which it is to register the temperature, having already very nearly the temperature of the water at that depth. It is, therefore, generally speaking, quite safe to despatch the messenger, which is to overturn the thermometer, so that it may arrive at the required depth not later than one or two minutes after the thermometer. This refers only to *oceanic* work. The physicist must himself test the actual thermometers which he has on board by observing them in still water and when moved at certain velocities in water, and from his own observations he will form his own opinion of how long the particular instruments with which he is supplied have to be left down, and then he will use his knowledge to guide his practice.

Application of Calorimetry to Hydraulics.—An interesting example of the application of calorimetry to problems of physical geography is afforded by some hydraulic experiments made by the writer in the Engadine in the summer of 1894. About a mile below the end of the Morteratsch glacier, the muddy stream which proceeds from the glacier is joined by the perfectly clear waters of the stream which descends from the summit of the Bernina pass, the waters of which drive the machinery for the supply of electricity to Pontresina. In the afternoon the glacier stream is running strongly, and its temperature was found to be 1° C. The temperature of the water of the Bernina stream was 11° C. Two or three hundred yards below the confluence, where the waters had been well mixed, the temperature of the water was 2·5° C. If we represent by M the flow of the Morteratsch and by B that of the Bernina stream, we have the relation $M : B :: 10 : 1·5$, whence we have $B = 0·15$ M, or the stream below contains 85 per cent. of Morteratsch water and 15 per cent. of Bernina water.

Temperature of Insolation.—In a meteorological outfit it is usual to include a thermometer with blackened bulb enclosed in an external glass tube. This is to be exposed to the direct rays of the sun until it rises to a temperature which remains stationary. This tem-

perature is to be observed. When taken in connection with the temperature in the shade this is to furnish information regarding the calorific action of the sun's rays. It is in a position to furnish reliable information of this kind only if the thermal mass or water value of the bulb and its term of cooling are known. These are not commonly supplied. Even if they were supplied it is doubtful if the instrument would furnish any trustworthy information; the external glass envelope introduces so much disturbance.

When a thermometer, whether its bulb be blackened or not, is exposed to the direct rays of the sun, its temperature rises at first rapidly, then more and more slowly until finally it reaches a temperature at or about which it remains steady, provided that it is in a place where the air is still and its temperature constant. While its temperature remains steady the thermometer is continually receiving heat from the sun's rays and giving it off to its surroundings, and the meaning of the constancy of its temperature is that the receipt and expenditure of heat per unit of time are equal.

If we know the thermal mass of the bulb of the thermometer and its term of cooling and the difference between its temperature and that of the air, we can calculate the rate at which it is losing heat, and this, at the stationary temperature, is the rate at which it is receiving heat.

If the thermometer is exposed with its axis perpendicular to the direction of the sun's rays, then it receives the rays which fall on a surface equal to the axial sectional area of the bulb. Consequently, the heating power of the bundle of solar rays having this sectional area is equal to the heating power of the thermometer when the excess of its temperature above that of the medium has become constant. This is rigorously true of that portion of the pencil of rays which penetrates the bulb of the thermometer. If the rays have had to traverse the windows of a room, some of the rays are absorbed by the glass, and a very large portion is dissipated by reflection from it. Further, even a blackened bulb does not transmit and absorb all the heat rays that strike it.

If two thermometers of different pattern are exposed side by side to the direct rays of the sun, they usually assume very different stationary temperatures, even although their graduation may be perfectly exact. This is to be expected, because thermometers of different pattern are sure to differ considerably both in term of cooling and in thermal mass. The nearest approach to equality in these particulars is found amongst common thermometers of the same pattern, which are turned out in large quantities at a time.

Example of the Method of Determining the Calorific Power of the Sun's Rays, which strike the bulb of a Thermometer and are absorbed by it; and of the difference between different thermometers in this respect. —The following observations were made with two thermometers of very different pattern. They were hung side by side in a room exposed to the powerful winter sun at St. Moritz, in the Engadine, between 11 and 11.30 a.m. on February 26, 1901. The thermometers are designated A and B. A is an ordinary German thermometer, divided into whole degrees on a milk-glass scale and its bulb was coated with silver. B was an English thermometer with solid stem, and divided into tenths of a Centigrade degree, each degree occupying a length of 1 cm. Its bulb was not coated in any way. The particulars relating to the bulbs were obtained by mensuration as above described. The mean altitude of the sun was 33° and cos 33° = 0·84; the axial sectional area of each thermometer has to be multiplied by this factor in order to obtain the effective area exposed, or rather to obtain the sectional area of the bundle of rays which strikes the bulb of each thermometer.

TABLE XVIII.—SPECIFICATION OF THE THERMOMETER.

Designation of thermometer			A	B
Diameter of bulb	cm.	*a*	0·637	0·471
Length of equivalent cylinder	cm.	*b*	2·3	2·4
Volume of bulb	cc.	*c*	0·7334	0·4181
Water value of bulb	grms.	*d*	0·3375	0·1923
Area of external surface	cm.²	*e*	4·92	3·727
Area of axial section	cm.²	*f*	1·465	1·130
Effective area of ditto	cm.²	*g*	1·230	0·950
Term of cooling	seconds	*h*	250	120

In Table XVIII. we have the specifications of the bulbs of the thermometers. It will be observed that the "length of the equivalent cylinder" *b* is given simply, in place of the cylinder and two hemispheres, as in the case of thermometers with large bulbs. The volume of the bulb *c* is found by multiplying the circular area corresponding to the diameter *a* by the length of the equivalent cylinder *b*. The water value of the bulb is $d = 0{\cdot}457\,c$. When this table was calculated, 0·457 was used as the specific heat per unit volume of the bulb, instead of 0·475, which was adopted later. It has not been thought necessary to recalculate the table. The area of external surface is the circular area of the diameter, added to the product of the length of the equivalent cylinder and its circumference. The

area of axial section is the product of the diameter of the cylinder and its length, and the effective axial area (g) is the axial section multiplied by 0·84; g is proportional to the quantity of the sun's rays, which strike the bulb in unit of time. The term of cooling, h, is given in seconds, and its reciprocal $\frac{1}{h}$ is the fraction of the excess of heat lost per second during cooling.

TABLE XIX.—EXAMPLE OF CALORIMETRIC USE OF THERMOMETERS FOR DETERMINING THE RADIANT HEAT WHICH THEY ABSORB.

Designation of thermometer .		A	B	A	B	A	B
Stationary temperature reached in sun's rays . . . . °C.	k	21°·25	18°·5	22°·15	19°·1	22°·4	19°·2
Difference between stationary temperature and that of the air	l	6°·25	3°·5	7°·15	4°·1	7°·4	4°·2
Corresponding excess of heat in each bulb . . gr. °C.	m	2·110	0·673	2·406	0·788	2·498	0·808
Loss of heat per second . .	n	0·00844	0·00561	0·00962	0·00657	0·00999	0·00673
Ditto per square centimetre of effective axial sections . .	p	0·00686	0·00590	0·00782	0·00691	0·00812	0·00706
Ratio $p_A : p_B =$	q	0·860		0·896		0·869	

Designation of thermometer .		A	B	A	B
Stationary temperature reached in sun's rays . . . . °C.	k	23°·1	19°·6	22°·4	19°·2
Difference between stationary temperature and that of the air	l	8°·1	4°·6	7°·4	4°·2
Corresponding excess of heat in each bulb . . gr. °C.	m	2·734	0·885	2·498	0·808
Loss of heat per second . .	n	0·0109	0·00738	0·00999	0·00673
Ditto per square centimetre of effective axial sections . .	p	0·00889	0·00775	0·00812	0·00706
Ratio $p_A : p_B =$	q	0·872		0·869	

In Table XIX. five separate observations of the stationary temperature reached by the thermometers side by side are given. The temperature of the air was 15°·0 C. The excess of heat in each bulb is $m = l\,d$, or the water value of the bulb multiplied by the excess of its stationary temperature above that of the air. The loss of heat per second $n = \frac{m}{h}$ as was above described; $p = \frac{n}{g}$ is the loss of heat per second referred to unit area of effective axial section. It has been pointed out that g, the effective axial area, is the sectional area of the bundle of solar rays which strikes the bulb, and it is therefore proportional to the supply of radiant heat by the sun to the thermometer. But when the temperature of the thermometer in the sun has become

stationary it is dissipating the whole of the heat which it is receiving. Now n gives the rate at which it is cooling, in gramme-degrees* (gr.°C.) per second; therefore the bundle of sun's rays of sectional area g is supplying heat at the rate of n gr.°C. per second, and $p = \frac{n}{g}$ is this rate for a bundle of rays of 1 square centimetre section. It will be seen that all the values of p given by thermometer B are lower than those given by A. In line q we have the ratio of $p_A : p_B$, and it will be seen that the values of q agree very well with each other. The mean value is 0·873, the extremes being 0·860 and 0·896; that is to say, thermometer B indicates 13 per cent. less heat than thermometer A for 1 square centimetre of sun's rays. Yet A has a silvered glass bulb and B has a plain uncoated glass bulb. It is possible that to this difference is due the difference in the results obtained. The silvered bulb dissipates by reflection some of the heat which strikes its metallic surface, but whatever is not reflected by this surface passes into the bulb of the thermometer. In the case of the uncoated glass bulb there are two surfaces of reflection, namely that separating glass from air and that separating glass from mercury. The heat which has passed through the outer glass surface has still to pass the inner surface, where some of it is rejected by reflection.

Taking the maximum value of p, namely 0·00889 gr.°C. of heat supplied per square centimetre per second, and multiplying it by 60, we have 0·533 gr.°C. per square centimetre per minute. This is the heat actually taken up by the silvered bulb of a thermometer from 1 square centimetre of the rays of the winter sun, which have passed obliquely through a glass window. The sky was quite clear and cloudless, but the sun's zenith distance was 57°. In order to allow for this, we use the formula given by Sir John Herschel,† from which we obtain the value of the *solar constant*

$$A = \frac{0 \cdot 533}{(\frac{2}{3})^{1 \cdot 84}} = 1 \cdot 1114 \text{ gr.°C. per square centimetre per minute,}$$

where $\frac{2}{3}$ is the *transmission coefficient* of the air for heat and $1 \cdot 84 = \sec. 57°$.

Two-thirds of this, or 0·7409, would then be the heating power of the rays of the vertical sun at the surface of the earth at a height of 1850 metres above the sea. This calculation has been carried out

* It is convenient to give compound names to compound units; they then explain themselves. One gramme-degree (1 gr.°C.) is the heat required to raise the temperature of one gramme of water by one Centigrade degree. Names such as calorie or therm are indefinite, and may be confusing.

† 'Meteorology,' by Sir John Herschel, Bart., Edinburgh, 1861, p. 10.

in order to make the example complete, and not as an experimental determination of the calorific power of the sun's rays.

At the same time it illustrates the principle of the *actinometric method* of determining the heat of the sun's rays, which has been much used.

Apart from the annual cycle of variation of the sun's distance from the earth, there is no reason to expect any measurable variation in its heating power. Therefore the principal object to be attained is to find the maximum heating power of the sun under the most favourable circumstances. This is perhaps best given by the calorimeter depending on the rate of generation of steam,* which was designed by the writer, and used by him in Egypt in May 1882. The values of the solar constant obtained with the actinometer by observers of the highest standing differ greatly, and some of them are certainly exaggerated. What we want to know in physical geography is how much heat is quite certainly received from the sun by a given area of the earth's surface exposed perpendicularly to its rays in a given time. With the writer's steam calorimeter the highest rate actually realised was 16·6 grms. of water converted into saturated steam of the same temperature per minute on an area of 1 square metre when the sun's zenith distance was 20°. This is equivalent to 17·04 grms. steam generated by a vertical sun on the same area. The latent heat of steam at 100° C. is 535 gr.°C. per gramme, therefore the generation of 17·04 grms. of steam of 100° C. out of the same weight of water of the same temperature requires 9116 gr.°C. of heat; and this is the amount of heat which can with certainty be extracted, per minute, from a bundle of sun's rays of 1 square metre sectional area at the sea level when the sun is at the zenith. The mechanical equivalent of heat is taken at 425 kilogramme-metres (kgm.) of work per kilogramme-degree (kg.°C.) of heat, or per 1000 gr.°C. Converting 9116 gr.°C. at this rate we obtain as its equivalent in work 3875 kilogramme-metres (kgm.). This amount of work is done in one minute. One horse-power, or the rate at which the standard horse can work is taken at 4500 kgm. per minute; *therefore the working value of the sun's rays at the sea level is at least* 0·87 *horse-power per square metre for a vertical sun.* The total area of the bundle of sun's rays which is at all times being intercepted by the earth is the area contained by its great circle, and this is taken at

* 'On a Solar Calorimeter used in Egypt in 1882,' by J. Y. Buchanan. *Proceedings of the Cambridge Philosophical Society* (1900), vol. xi. pp. 37, 74; and *Nature* (1901), vol. lxiii. p. 548.

130×10^{12} square metres. Therefore the working value of the sun to the earth is at least 113×10^{12} horse-power. This figure depends on the amount of steam actually generated in a particular instrument; but no instrument is perfect, therefore the above figure falls short of the truth. One horse-power per square metre has been taken as a probable work-value of the sun's vertical rays at the level of the sea. This is equivalent to 1·06 gr.°C. per square centimetre per minute. In accepting these values of the solar heat constant at the sea level we are assured that we are not exaggerating.

It is impossible to determine, or to estimate exactly, how much of the sun's heat is absorbed in its passage through the atmosphere. We have seen that Herschel estimates the amount transmitted to be two-thirds of the amount which arrives at the earth's orbit, leaving one-third to be absorbed. The true amount absorbed is probably rather under than over this figure.

Taking 1 horse-power per square metre as the total work-value of the sun's rays, and remembering that the mean distance of the earth from the sun is 212 times the length of the sun's radius, we find that the rays emitted by 1 square metre of the sun's surface are spread over 212^2, or in round numbers, 45,000 square metres of the earth's surface. Therefore, *the probable work-value of* 1 *square metre of the sun's surface is at least* 45,000 *horse-power.*

It is useful to note that the sun's heating power at the distance of the planet Mercury is 6½ times, and at that of Venus it is twice its value at the Earth's distance.

The Necessity of the Knowledge of Calorimetric Factors in Connection with the Use of the Barometer.—It is an interesting historical fact that Fahrenheit, to whom we owe the thermometer as a physical instrument of precision, got the idea of filling his thermometer with mercury by observing and being troubled by the irregularities of the barometer due to change of temperature. It is also probably not altogether accidental that the length of one degree of his thermometric scale corresponds to one ten-thousandth of the volume of the mass of mercury used in the thermometer.* If mercury expands by $\frac{1}{10000}$ for every Fahrenheit's degree, then an error of 1° F. in the estimation of the temperature of the barometer introduces an error in the barometric pressure of $\frac{1}{10000}$ of the whole height of the column of mercury. If that height is 30 inches the error is three-thousandths of an inch. If the height is 760 mm. the error is 0·076 mm. It is obvious, therefore, that unless we can be perfectly certain that the tem-

* This fact gives Fahrenheit's thermometer a genuine title to the name *centigrade*, which Celsius' scale lacks.

perature of the barometer is within $\frac{1}{3}°$ F. of what we take it to be, there is no sense in reading the barometer to units in the third decimal place of the inch, and still less so to units in the second decimal place of the millimetre. But, it will be said, we have the "attached thermometer," and it can easily be read to $\frac{1}{10}°$ F. Completing the suggested syllogism, we have:—Now the temperature of the attached thermometer is always identical with that of the mercury of the barometer to which it is attached; therefore, we know the temperature of the mercury of our barometer to $\frac{1}{10}°$ F.; and by consequence we are justified in reading our barometer to 3 in the fourth decimal place of the inch, and to 7·6 in the third decimal place of the millimetre. If the premises are granted, the conclusion is necessary. But the second premise is true only in certain conditions which do not usually obtain. If the temperature of the room in which the barometer is hung is invariable, the premises may be granted and the conclusion is valid. If the temperature is not invariable, the premises cannot be granted, and the conclusion is false. Sufficient attention is not paid to this source of uncertainty in barometric readings. After what has been said about the term of cooling of a thermometer, the reader will easily see where the fault lies and how to remedy it. In so far as the effect of temperature on the length of the mercurial column is concerned, the barometer is a thermometer with a bulb of the volume and thermal mass of the column of mercury. The term of cooling of this mass must be very much greater than that of the attached thermometer; so that if at any epoch the two chanced to be at exactly the same temperature, and the temperature afterwards went through the usual diurnal changes, they would never again have the same temperature, except for a moment of time when their thermal paths happen to cross. The only adequate "attached thermometer" is one which has a bulb which is a copy of the barometer, has the same thermal mass and the same term of cooling, and is exposed to exactly the same condition as the barometer. In important central stations the standard barometer should be accompanied by such a thermometer. In standardising stations nothing but absolute uniformity of temperature should be admitted. The need of correction is the confession of imperfection. In exact work no correction should be admitted which it is mechanically possible to exclude.

In Europe and North America, and generally in countries where for a part of the year dwellings have to be artificially heated, the condition of uniformity of temperature is not secured of itself, and it may be troublesome to provide it. The Paris observatory has its

classical cellars of invariable temperature. What could be artificially provided centuries ago can be provided now. For a central national standardising institution such a chamber is indispensable, if its certificates are to have the value which ought unquestionably to belong to them.

In tropical, and still more in equatorial regions, where the diurnal variation of temperature is small and its rate slow, uniformity of temperature, sufficient for a first-class meteorological station, is easily obtained in any well-constructed building, and consequently perfection is more easily attained there than in regions more remote from the equator.

But the ideal conditions of temperature for a first-class physical laboratory are to be found on board of a large wooden ship at sea between the tropics. The temperature of the surface-water does not vary by 1° Fahr. in twenty-four hours. The temperature of a shaded thermometer on deck may vary by two or three, or even more, degrees, according to the greater or less efficiency of the shade, but *the true temperature of the air varies as little as does that of the sea surface.*

During the three years that the *Challenger* sojourned in tropical seas the writer had daily occasion to notice this fact, and to some extent, though inadequately, to take advantage of it. In particular, a series of experiments was made on the compression of deep-sea thermometers, which required practically absolute uniformity of the temperature of the air. This was found on the main-deck, where the compression apparatus was installed. The main-deck of the ship was protected by the spar-deck, and by an awning above that. It was ventilated by twenty-eight open gun-ports. All passages were made under sail; therefore, when under way, one side of the ship was always definitely a weather side and the other definitely a lee side, and the gun-ports afforded unobstructed passage to whatever wind was blowing. The main-deck of the *Challenger* was, therefore, a perfect "thermometer screen," and tested in these perfect conditions the air preserved as uniform a temperature as the water. While the compression experiments were being made the variation of temperature during the working part of any one day was not greater than one-tenth of a Centigrade degree.

It would be impossible on shore to provide such conditions of work. Hence, so far as temperature conditions are concerned, and other things being equal, observations of the barometer on board ship in tropical regions are entitled to more weight than those made elsewhere.

Giving effect to these considerations, we have the following—

Directions for Hanging a Barometer on Board Ship.—The barometer is to be hung in the inhabited part of the ship, in a saloon or cabin, not on deck, but with a substantial deck above it, and out of the radius of either sidelights or skylights. In such conditions the temperature of the barometer and that of its attached thermometer may agree.

The Effect of Change of the Force of Gravity on the Pressure of the Atmosphere and on the Height of the Barometer.—If we consider a siphon-barometer, and take the plane of the surface of the mercury in the open limb as *datum level*, all that is above it in one limb exercises the same pressure as all that is above it in the other. But all that is above it in the outer or open limb is the column of the atmosphere, and all that is above it in the inner or closed limb is the column of mercury: therefore, the weight of the column of mercury is the same as the weight of the column of air. The weight of a body is the product of its mass into the force of gravity at the place. The force of gravity is the same * in both limbs of the barometer, therefore the mass of the column of air is the same as the mass of the column of mercury. If, other things remaining the same, we reduce the density of the earth to one-half, there will still be equilibrium between the columns of air and of mercury in the barometer. The height of the barometer will be unaltered, yet the pressure of each of these columns on its base will now be only one-half of what it was before, because the pressure of the column depends on its weight, and the weight is proportional to the force of gravity. In both cases we shall have correctly the *height of the barometer*, and it will have remained unaltered, but with equal heights of the barometer the pressure of the air will, in the latter case, be one-half of what it was in the former.

The force of gravity is not the same at all points of the earth's surface. Hence arises the necessity for the *gravitation correction*, in order, from the observed height of the barometer, to ascertain the true pressure of the atmosphere expressed in stardard units, that is, in millimetres of mercury having a temperature of 0° C., and subject to the attractive force of gravity which it would experience at the sea-level in latitude 45°. This force generates in one second a velocity of 980·6 centimetres per second.

If we consider the layer of air of 1 mm. in thickness which is contiguous to the surface of the mercury in the outer limb of the

* Such slight differences as are due to the greater distance of the centre of the earth from the centre of gravity of the atmospheric column than from that of the mercurial column are here neglected.

barometer, and is pressed down upon it by the weight of the whole atmospheric column above it, we see that the elasticity of this thin layer of air exactly balances the pressure of the air above it and that of the mercury below it. The tension of this layer of air is equal to the atmospheric pressure. Imagine the density of the earth to be reduced by one-half; the height of the barometer is still the same, but the pressure on both sides of the thin layer of air is reduced to one-half; therefore it expands to double its volume, and the thickness of the layer becomes 2 mm., and by consequence its tension has been halved.

Imagine now a thin layer of water on the surface of the mercury in the outer limb of the barometer. It is pressed down by the weight of the atmospheric column, and it is pressed up by that of the mercurial column. The tension of the air in contact with the water surface is equal to the pressure of the atmospheric column. Let the height of the barometer be 735·5 mm., then taking the mean force of terrestrial gravity at the sea level in lat. 45°, the atmospheric pressure is 1 kilogramme per square centimetre, and the tension of the air in contact with the water is also 1 kilogramme per square centimetre. Let the layer of water be heated. When it arrives at a temperature of 99°·1 C. the tension of its vapour is exactly 1 kilogramme per square centimetre, and it is therefore equal to the atmospheric pressure, and any further supply of heat will cause the water to boil at the temperature of 99°·1 C. Let the water be cooled down again; and let the density of the earth be reduced by one-half. Then the height of the barometer will remain unaltered at 735·5 mm., but the pressure of the air will be halved and will be only 0·5 kilogramme per square centimetre. Let the water now be warmed. When the temperature of the water arrives at 80°·9 C. the tension of its vapour is exactly 0·5 kilogramme per square centimetre, and any further supply of heat will cause the water to boil at this temperature.

It is evident then that if we know the relation between the tension of aqueous vapour in kilogrammes per square centimetre and the temperature, we have in the boiling-point of water a means of measuring the true pressure of the atmosphere in which it is boiling.

But we have seen that the pressure of the atmosphere is proportional to the quantity of the air that is in the column which rests on the surface of the boiling water, and to the force of gravity or the earth's attraction which pulls it towards its centre. Suppose the force of gravity constant, the boiling-point of water will be the

lower the less air there is in the column above it, or the greater the height of the locality above the level of the sea. If we know the law regulating the relation between pressure of the atmosphere and elevation above sea level, we have in the boiling-point of water a means of determining the elevation, because the tension of the vapour of the boiling liquid is equal to the tension of the air on its surface, and the tension of the air at the bottom of a column of it is equal to the pressure of the column, and the relation between air pressure and altitude is known.

If the quantity of air in the column resting on the boiling water remain constant, and the force of gravity, or the attractive force of the earth on a particle at the surface of the water be altered, then the pressure of the column of air on the surface of the water and the tension of the air at the bottom of the column will be altered correspondingly.

If the force of gravity has been increased, the pressure of the air and the tension of the air at the bottom of the column will be increased; and if the temperature of the water remain the same the tension of its vapour will be less than the tension of the air in contact with it, and it will cease to boil. If further heat be supplied to it, its temperature will rise to that at which the vapour tension of the water is equal to that of the increased tension of the air at its surface, and the water will again boil.

If the force of gravity has been reduced, the pressure of the atmosphere and the tension of the air in contact with the boiling water will be reduced. The vapour tension of the water will then be higher than that of the air in contact with it, the water will be superheated and will boil for a time without any further supply of heat, the *super-heat* in the water being sufficient. When this is exhausted, the temperature of the water will be reduced to that at which its vapour tension is the same as the reduced tension of the air in contact with it, and with a further supply of heat it will continue to boil at this temperature.

During these changes of the force of gravity and consequent changes of the boiling-point of water, the height of the barometer has remained without change, because the changes of force of gravity act equally on both limbs of the siphon.

In the same way a balance which is loaded with a litre of water on the one pan and a kilogramme of platinum on the other remains in equilibrium, whatever changes may be made in the force of gravity. If, however, the litre of water were weighed on a *spring* balance its weight would vary in the same proportion as the force of gravity.

Its weight on a spring balance is the measure of the power which it has to overcome a certain constant resistance, the resilience of the spring. The whole of this power is conferred on it by the force of gravity. By virtue of its mass alone it has no such power. Hence, in the case considered, when the density of the earth is supposed to be halved, the weight of the litre of water would be halved also, and it would be registered as 500 grammes on the scale of the spring-balance. The same would apply to the kilogramme of platinum. The spring-balance would give its weight as only 500 grammes, and it is evident that under the altered conditions of gravity they would still balance each other in the opposite pans of a pair of scales. Like the hypsometer, the aneroid barometer measures the pressure of the air, not the height of the barometer. It is a spring-balance, whilst the mercurial barometer is a pair of scales.

The gravitation correction for the barometer, as supplied in meteorological instructions, is based on the assumption of a homogeneous earth, and refers only to varying distance of the station from the centre of the earth. The force of gravity varies inversely with the square of this distance. It is obvious that there will be some difference between the force of gravity at the level of the sea and that at the top of a high mountain in the neighbourhood. We have taken the mean radius of the sphere to be 6371 kilometres. At a height of 1000 metres above the sea the force of gravity is less than it is at the level of the sea in the proportions $6372^2 : 6371^2 = 0 \cdot 99968$. At a height of 5000 metres the relative reduction is 0·99843, and at 10,000 metres it is 0·99687.

Owing to the spheroidal shape of the earth, places at the sea level are at different distances from the centre of the earth if they are situated in different latitudes.

The most recent values of the dimensions of the earth's spheroid are—

Semi-axis major	6378	kilometres.
Semi-axis minor	6356	„
Difference	22	„

The greater radius is the equatorial and the smaller the polar, therefore the force of gravity at sea level is a maximum at the poles and a minimum at the equator, and the relation between them is 0·99311. The difference between the equatorial and the polar radii is about three times the height of the highest mountain on the earth's surface.

In order to illustrate these remarks Table XX. has been constructed. It is supposed that the barometer has been observed at a temperature of 0° C., and at the sea level in the latitudes given in the first column, and that it stands always at a height of 735·5 millimetres. As the force of gravity at the sea level increases from the equator to the pole, this constant barometric height corresponds to a true atmospheric pressure, which increases as the pole is approached. This is given in the second column in grammes per square centimetre. In the third column these pressures are given in terms of the height of a column of mercury at 0° C. at the sea level, *and in latitude* 45°. In the fourth column the temperature of saturated steam, or the boiling-point of water under these true pressures is given. It will be seen that, other things being the same, *the boiling-point of water at the sea level is* 0°·147 C. *higher at the pole than it is at the equator*. This figure is based on the assumption that the mass of the earth is homogeneous, or if heterogeneous, that it is symmetrically heterogeneous with reference to its centre. It is also assumed throughout the whole of this argument, that there are no fluctuations in the atmosphere itself, and that the quantity of air in a column having unit area of base, at the sea level, is everywhere the same.

TABLE XX.—GIVING THE TRUE ATMOSPHERIC PRESSURE AND THE BOILING-POINT OF WATER CORRESPONDING TO A BAROMETRIC HEIGHT OF 735·5 MILLIMETRES AT 0° C. AND AT THE SEA LEVEL IN DIFFERENT LATITUDES.

Latitude.	Atmospheric Pressure.		Corresponding Temperature of Saturated Steam, or the Boiling Point of Water.	Latitude.	Atmospheric Pressure.		Corresponding Temperature of Saturated Steam, or the Boiling Point of Water.
	Grammes per Square Centimetre.	Millimetres Mercury at 0° C. and Gravity as at Latitude 45°.			Grammes per Square Centimetre.	Millimetres Mercury at 0° C. and Gravity as at Latitude 45°.	
	gr. p. cm².	mm.	°C.		gr. p. cm².	mm.	°C.
0°	1002·65	733·55	99·012	45°	1000·00	735·50	99·087
10°	1002·50	733·66	99·017	50°	999·54	735·84	99·099
20°	1002·04	734·00	99·029	60°	998·67	736·48	99·123
30°	1001·33	734·52	99·048	70°	997·80	737·00	99·142
40°	1000·46	735·16	99·072	80°	997·50	737·34	99·155
45°	1000·00	735·50	99·087	90°	997·35	737·45	99·159

In the tabular example it is imagined that we carry a standard barometer from the equator to the pole, and that we read it at the sea level in certain latitudes, the barometer being entirely and exactly at the temperature of melting ice; and it is further imagined that the height of the barometer at each of these stations is found to be the same, namely, 735·5 millimetres.

If we assume that the force of gravity is the same at the sea level in all latitudes, then the fact that the atmosphere everywhere exercises the same pressure as a certain standard length of mercury, is evidence that the mass or the quantity of air in a column of the atmosphere having the same base is, at the sea level, everywhere the same. If the height of the standard barometer had not been the same at each of these stations, and at the same time it was known that the force of gravity did not vary, then the conclusion would be necessary that the quantity of air in the atmospheric column at the sea level is greater in one latitude than in another.

If the height of the standard barometer is, as postulated in the table, the same at each of the stations, and if it is known that the force of gravity is not constant, then the height of the standard barometer of itself gives us no information regarding the pressure of the atmosphere. The constancy of the height of the standard barometer justifies no other conclusion than that the pressure of the atmosphere is different in different latitudes.

If the law of the variation of the force of gravity with change of latitude is known, then the constant height of the barometer allows us to arrive at the *relative* pressure of the atmosphere at different latitudes. If, in addition, the absolute value of the force of gravity at any one latitude is known, the constant height of the standard barometer enables us to conclude what is the absolute pressure of the atmosphere at the different latitudes.

If the distribution of matter in the earth is homogeneous, and if the force of gravity at the sea level varies, then the conclusion is necessary that different stations at the sea level are at different distances from the centre of the earth, or they are at different *altitudes*, referred to this point as fundamental datum.

If the law which connects the variation of the force of gravity with distance from the attracting centre is known, the distance of the sea level in any locality from the centre of the earth is at once ascertained by determing the force of gravity there; hence the gravitational method of determining the figure of the earth. Here it must be remarked that a perfect survey of the *figure* of the earth may be given without affording any information about its *size*.

To return to the barometric data in the table, we see that while the height of our standard barometer was the same, 735·5 mm. at every station, the indications of the hypsometer or the boiling-point varied. It has been shown that the *height of the barometer* is not affected by change in the force of gravity, but that *the pressure of the atmosphere* is so affected; we might conclude that in the temperature

of saturated steam, or the boiling-point of water, at the sea level, we have a method of determining the force of gravity at any place at that level. But we must be on our guard. Our knowledge of the relation existing between the boiling point of water and the pressure on its surface is derived from observations of the barometer. Therefore, from the boiling point of water we cannot get *absolute* data with regard to the force of gravity. But it may be that it can afford information about the *variations* of the force of gravity.

For instance, we observe our standard barometer having the temperature of melting ice at the sea level, in lat. 20°, 45° and 70°, and at each of these places its height is 735·5 mm.; we apply the usual correction to reduce this barometric height to the equivalent height when the mercury is exposed to the same gravitational force of attraction. By convention, the standard force of terrestial attraction is taken to be that exerted at the sea level in lat. 45°. The barometric heights thus adjusted are now 734, 735·5 and 737 mm., and these columns of mercury under the influence of standard gravity exercise pressures of 1002·04, 1000 and 997·8 grm. per square centimetre. It results from experiments, principally by Regnault, on the relation between the boiling point of water and the height of the standard barometer, that at these true pressures water boils at 99°·029, 99°·087 and 99°·142 C. respectively.

Supposing that we take the hypsometer to these latitudes, and that we determine the boiling point of water with every care at each latitude at the sea-level when the standard barometer at 0° C. stands at 735·5 mm., and we find that the boiling point is the same, namely 99·087° C. at all these latitudes, then we conclude that the true pressure of the atmosphere at each of the localities is 1000 grm. per square centimetre. But we know from the geodetic determination of the figure of the earth that the sea-level is nearer the centre in lat. 70° than it is in lat. 45°; and nearer in lat. 45° than in lat. 10°. If the earth is homogeneous the force of gravity *must* be greater at lat. 70° than at lat. 45°, and at lat. 45° than at lat. 10°. But from the identity of the height of the barometer at the three localities we know that the *mass* of the atmospheric column is the same at the three places, and from the identity of the boiling point of water we know that the *weight* of the three columns or the atmospheric pressure is the same in the three places. As the force of gravity depends only on the mass of the attracting body and on the distance of its centre from the attracted body, and we find that, when this distance is varied in a certain measure no alteration is produced in the effective force of gravity the conclusion is necessary, that the effect

of variation of distance has been exactly compensated by variation of the effective attracting mass. In the example taken we find the force of gravity in lat. 10° greater than it should be, and in lat. 70° less than it should be.

As the attraction of the whole earth on a particle at its surface is the sum of the attractions of all the particles that make up its mass; and as the attractive force of each particle of the earth's mass on the particle at its surface is inversely proportional to the square of its distance from that particle, it is evident that the particles in the vicinity of the attracted body will exercise, mass for mass, a much greater attraction on the body than the particles that are more remote, for instance, at the opposite end of the diameter of the sphere. Therefore, the occurrence of rocks of relatively high density near the surface in a locality may easily cause an exaggerated force of gravity in the locality, and the occurrence of rocks of relatively low density may cause an analogous deficiency of local gravitational attraction.

Looking to the great variety of mineral substances which we meet with in the surface crust of the earth, and to the differences of their densities, it is not surprising that recent observations with the pendulum show that local peculiarities of the force of gravity are the rule and not the exception. The differences in neighbouring localities are not usually great, but the pendulum is an instrument of almost infinite delicacy, so that with patience the gravitational map of a district can be correctly constructed, no matter how slight the differences may be.

It will be evident from the examination of Table XX., that by the combined use of the barometer and the hypsometer we have in our hands the means of determining local deviations of the force of gravity from its normal value.

Rule for detecting the deviation of the local force of gravity from the normal by simultaneous observations of the standard height of the barometer and of the boiling-point of water.

Determine the height of the barometer at 0° C. Apply the gravitation correction for distance of the locality from the centre of the earth, so as to reduce it to its equivalent height when the mercury is exposed to the attraction of the standard force of gravity, as at the sea-level in latitude 45°. Determine the boiling point of water at the same time and place. Refer to the tables connecting this boiling point of water with standard barometric pressure, and from them take out the boiling point corresponding to the observed standard barometric pressure. If the tabular and the observed boiling points are

identical, then the force of gravity at the place is normal. If the tabular boiling point is higher than the observed boiling point, then the local force of gravity is less than the normal; if it is lower than the observed boiling point, then the local force of gravity is greater than the normal. In arriving at these conclusions, we postulate the complete exactness of the tables giving the relation between barometric pressure and the temperature of saturated steam, and of those giving the normal gravitational correction for latitude and for height above the sea.

The use of the hypsometer along with the barometer may give valuable results at sea. It may give us a means of *divining* changes of depths of the ocean, especially in tropical latitudes where, when the sea is calm, all the conditions for such experiments are most favourable. On land, the subject has been taken up with great zeal by Professor Mohn,* the distinguished head of the Norwegian Meteorological Service. He has already published a preliminary report, and further reports from him will be expected with interest. In his hands this method will be thoroughly tested in all directions.

It is not suggested that such observations should be made by the Antarctic Expedition. The margin of 0°·147 C. between the normal boiling point at the poles and at the equator shows that very fine thermometers would be required, and many other refinements are necessary. It is quite evident that the height of the barometer at 0° C. can be arrived at with the requisite certainty only if the barometer has been hanging for at least a day in a room of uniform temperature. Of course the whole of the working part of the thermometer must be immersed in the steam. Correction for an exposed portion of the mercurial thread of the thermometer is quite inadmissible. The combined use of the barometer and the thermometer has been discussed at this length because it affords an opportunity of arriving at precise ideas of the fundamental principles of both instruments, and of the uses to which each may be legitimately put.

A legitimate, and at the same time, an eminently practical use of the hypsometer is to *replace* the mercurial barometer in the determination of the atmospheric pressure, and in the comparison of barometers at distant stations. On all camping excursions it is necessary to have the means of boiling water, and except under stress of circumstances, it is boiled night and morning. Saturated steam is therefore produced in the ordinary day's work; it is only

* Das Hypsometer als Luftdruckmesser, von H. Mohn. Christiania, 1899.

necessary to provide the means of observing its temperature accurately.

The aneroid barometer has been mentioned as having, in some respects, the same advantages as the hypsometer, and it might be thought that the aneroid can, on such excursions, replace both the mercurial barometer and the hypsometer. But this is not so. The aneroid is a spring balance, and its spring soon gets tired, so that, for instance, on an excursion in mountainous countries, it might, on arriving in the evening at the camping place, show a certain pressure of the atmosphere, and the next morning it might show a different pressure, even although the real pressure had not varied in the interval. If the temperature of boiling water varies in the same place, it is proof that the pressure of the atmosphere has varied. But although the aneroid cannot replace the hypsometer, it may with advantage be used in connection with it for determining local variations of height or of atmospheric pressure during one day. The night and morning comparisons with the hypsometer give its *error and rate* for that day.

Examples of Rapid Variations of Atmospheric Temperature, especially during Föhn.

The following pages contain the record of *peripatetic* meteorological observations made at different times. They are reprinted from a paper * on this subject published in the Proceedings of the Royal Society in 1894.

"The variation of the temperature of the air in the course of a day is a matter of familiar observation. It depends in the first instance on the relative positions of the locality and the sun. The temperature is generally highest a short time after the sun has attained its greatest altitude above the horizon, and it is lowest some time after it has attained its greatest depression below the horizon. Observations made at regular intervals over the twenty-four hours show a more or less regular rise of temperature during the early part of the day and a similar fall of temperature during the latter part of the day and the evening. When the interval between the observations is diminished the regularity of the march of temperature is found to diminish also, but the great variability of the temperature of the air is best shown by the curve drawn by a recording ther-

* 'On Rapid Variations of Atmospheric Temperature, especially during Föhn, and the methods of observing them,' by J. Y. Buchanan, F.R.S. *Proc. R. S.* (1894), vol. lvi. p. 108.

mometer of sufficient sensibility combined with a clock movement of suitable velocity. Such an instrument draws a sinuous line which is generally smooth during the night and serrated during the day. The shape and the crowdedness of the teeth on the serrated daylight portion of the line have a close connection with, and are to a certain extent an indication of, the character of the existing weather. In general the indented character of the daylight curve is an indication of the disturbing influence of the sun on the equilibrium of the atmosphere, and this continues just as long as he is above the horizon; after sunset, the atmosphere quickly reverts to a state of greater stability."

It is only necessary to watch a thermometer during one or two minutes to be convinced of the great variability of the temperature of the air not only from one minute to another, but almost from second to second. This is most easily and most briefly shown by quoting the series of observations made at St. Moritz, in the Engadine, in February 1894.

"In the winter of this year I revisited the Engadine, and stayed for a fortnight at St. Moritz. As the room which I occupied faced due north, the window of it was convenient for making observations of the temperature of the air. From the 24th February to the 3rd March I made every morning a series of observations of the temperature of the air, beginning when there was just light enough to read the thermometer, and continuing till between 8 and 9 o'clock in the morning. At first I took the temperature every minute, but finding the oscillations of temperature very great, I reduced the intervals to twenty seconds, and sometimes to fifteen seconds. To print the observations *in extenso* would occupy too much space, but the striking features can be easily summarised. They are given in Table XXI. Excepting on the 26th February, when it was snowing all the morning, the observations embrace the interval of an hour or an hour and a half after sunrise. The time was devoted entirely to this object, and observations were made at as close dates as possible. Working alone, an interval of twenty seconds is quite convenient; shorter intervals cause hurry. The time immediately following sunrise is when one would expect the temperature of the air to rise continuously, if not regularly; but we see that so far from rising continuously and regularly the thermometer rises, falls, and remains stationary quite irregularly. On some days, as on the 28th February, these irregularities are comparatively few; on others, as on the 1st and 2nd of March, they are numerous. The largest rise or fall in twenty seconds is 0°·5 C. From experi-

TABLE XXI., GIVING RESULTS OF OBSERVATIONS OF THE TEMPERATURE OF THE AIR AND ITS VARIATIONS AT ST. MORITZ.

Date, 1894.	Time of observation.	Limits of temperature.	Interval between observations.	Number of intervals in which the temperature was observed to			Total number of intervals.	Maximum rise or fall in any one interval.	
				Rise.	Fall.	Remain constant.		Rise.	Fall.
		°	"					°	°
25 Feb. .	6.24 a.m. to 7.32 „	−8·0 −5·0	60	32	22	13	67	0·51	0·50
26 „ .	11.10 „ to 1.19 p.m.	+8·25 +3·5	20	32	33	61	126	0·13	0·50
27 „ .	6.55 a.m. to 8.40 „	+1·75 +5·35	20	80	43	45	168	0·37	0·47
28 „ .	7.0 „ to 8.2 „	−6·48 −1·0	20	103	37	45	185	0·25	0·20
1 March	6·30 „ to 7.30 „	−4·25 −2·1	15	93	68	80	241	0·25	0·20
2 „	6.38 „ to 8·6 „	−6·23 −2·03	13	158	118	131	407	0·23	0·18
3 „	6.30 „ to 8·6 „	−6·55 −1·68	20	120	89	77	285	0·28	0·20

ments in calm air outside and in still air in a room, we find that for this thermometer to rise or fall 0°·5 C. in twenty seconds the temperature of the air around it must be from 2°·25 C. to 4°·65 C. hotter or colder than the thermometer. Taking even the lowest of these values, we see how great the possible error is in measuring the actual temperature of the air at any moment with a thermometer, and the error is the greater the more sluggish the instrument is. In Table XXII. the detailed observations are given for a few minutes on the 26th of February, when the temperature was changing very rapidly. In the third and fourth columns the rise or fall of the observed temperature is given. In the fifth and sixth columns the corresponding differences between the temperature of the air and that of the thermometer which would cause the observed rate of change of temperature are given; with these and the observed temperatures we obtain the amended temperatures of the seventh column. Although it was snowing on the 26th, the air was perfectly still, and the rate of cooling corresponding to the 'term'

TABLE XXII.—TEMPERATURE OF THE AIR AT ST. MORITZ, OBSERVED AT INTERVALS OF TWENTY SECONDS.

Date, 28 February, 1894.			Observed temperature.	Difference.		Corresponding difference of temperature of air.		Amended temperature of air.	Differences of amended temperatures.	
				Fall.	Rise.					
			T. C°.	−	+	−t.	+t.	T' = T + t.	Fall.	Rise.
A.M. h.	m.	s.	°							
11	18	45	+ 5·88	..	..	..	..	6·48		
	19	5	6·00	..	0·12	..	0·60	6·60	..	0·12
		25	6·12	..	0·12	..	0·60	6·72	..	0·12
		45	6·25	..	0·13	..	0·60	6·25	0·47	
	20	5	6·25	..	..	..	..	6·25		
		25	6·25	..	..	..	..	5·25	1·00	
		45	6·00	0·25	..	1·00	..	4·30	0·95	
	21	5	5·62	0·38	..	1·70	..	3·37	0·93	
		25	5·12	0·50	..	2·25	..	4·12	..	0·75
		45	4·88	0·24	..	1·00	..	2·63	1·49	
	22	5	4·38	0·50	..	2·25	..	2·13	0·50	
		25	3·88	0·50	..	2·25	..	3·88	..	0·75
		45	3·88	..	..	..	..	3·28	0·50	
	23	5	3·75	0·13	..	0·60	..	3·75	..	0·47
		25	3·75	..	..	..	..	4·37	..	0·62
		45	3·88	..	0·13	..	0·60	3·88	0.49	
	24	5	3·88	..	..	..	..	3·28	0·50	
		25	3·75	0·13	..	0·60	..	3·15	0·13	
		45	3·62	0·13	..	0·60	..	3·12	0·03	
	25	5	3·50	0·12	..	0·50	..	3·00	0·12	
		25	3·62	..	0·12	..	0.50	4·00	..	1·00
		45	3·50	0·12	..	0·50	..	3·12	0·88	
	26	5	3·50	..	..	..	..	3·50	..	0·38
		25	3·50							

eighty seconds has been applied. Had the rate of cooling of the thermometer in the still air of a room been taken, the difference between amended and observed temperatures would have been nearly twice as great.

"*Characteristics of Föhn Weather.*—These observations show how rapidly the temperature of the air may vary even in ordinary weather. There is a class of weather which is generally known by its Alpine name *Föhn,* the distinguishing feature of which is the rapidity with which the temperature of the air changes from moment to moment, and the exceptionally high average temperature of the air.

"It has been most observed in the valleys stretching in a northerly direction from the main summit line of the chain of the Alps and takes the form of an abnormally warm wind blowing from the mountains towards the plain. It has largely occupied the attention of continental meteorologists, and more particularly it has been the subject of exhaustive investigations by Hann, who has shown by very strong evidence that its high temperature must be due to its compression in descending from a great altitude. In the descriptions of the Föhn, attention is almost exclusively directed to the high average temperature of the air, and no mention is made of its extraordinary variations, although every observer must have noticed them. They are so great as to be recognised at once by the sensations and at the same time so rapid as to elude almost every other method of estimation or measurement. It has also, I believe, not been before remarked that the true *Föhn* occurs in our own country and with its characteristics quite as well marked as in Switzerland. It is sometimes supposed that a great absolute height of mountain chain is required for its production; but this is not so. A relative height of 1000 to 1200 metres is quite sufficient for its production; and this is equally available on the west coast of Scotland and on the northern slopes of the Alps.

"Some observations were made in the summer of 1893, which was abnormally warm all over the north of Europe. In the beginning of July I observed the *Föhn* at Fort William, and in the latter part of August in the upper Engadine, and more particularly in the valley occupied by the Morteratsch glacier. Besides the observation of the varying temperature of the air itself, the investigation of the temperature gradient set up between the melting ice surface of the glacier and the hot winds blowing over it presented considerable interest. The curious fact was observed that while the hot wind was blowing over the glacier and melting the surface in abundance, the temperature of the air, as close to the ice as a thermometer could be applied without touching the ice, was never lower than 5°·5 C.

"In the beginning of July at Fort William the weather was very warm, and in the midst of very warm air still hotter blasts made themselves felt from time to time. The sensation was much the same as is produced when, on the deck of a steamer, the air passing the funnel strikes the face. These hot blasts lasted only for one or two seconds, and repeated themselves every minute or two. Their effect on a thermometer, freely exposed in the shade, was to keep the mercury in a constant state of motion, the temperature rising often

more than 1° C. in a minute, and falling again as much. The thermometers in the screens were also a good deal affected, though not nearly to the same extent as the freely exposed ones. The recording instruments, the clock motion of which was not sufficiently quick to draw the record out into an indented line, showed a broad band which measured the amplitude of the excursions of the instrument, though by no means the amplitude of the oscillations of the temperature of the air. This phenomenon was particularly observed on the 8th July, 1893. It was very warm, as the following observations of the thermometers in the large observatory screens will show :—

TABLE XXIII.

Hour.	9 a.m.	10 a.m.	Noon.	2 p.m.	4 p.m.
Dry bulb (°C.)	20·1	22·4	24·9	23·8	18·9
Wet bulb (°C.)	17·7	17·3	18·2	17·7	16·6
Vapour tension (mm.)	13·5	11·5	11·5	11·3	12·6
Relative humidity	77	58	49	52	77

"It was during the heat of the day, from 10 a.m. to 2 p.m., that the hot puffs made themselves most felt; but I found it impossible to measure their temperature, owing to the thermal inertia of the thermometers. The puffs lasted not longer than one or two seconds, and their temperature, to judge by the sensation, was rather higher than that of the body. The thermometers had only begun to rise when the heating ceased, and they fell back again. From the figures in the above table, it will be seen that the temperature of the air at noon reached 24·9° C., a very high figure for a station in nearly 57° north latitude. Along with the great rise of temperature there is a fall of absolute as well as of relative humidity, indicating that the air has come from a greater altitude. Attempts to measure the actual temperatures of the hot puffs gave no satisfactory result."

These few lines will give an idea of the nature of the weather called *Föhn*. The temperature of the air is abnormally high, and it is very unequally distributed through the mass of the air. The atmosphere seems rather to be made up of sheets of air of very different temperature; it is also very dry.

In the Antarctic regions there are plenty of high mountains and sharp gradients, and it is certain that conditions described as characterising *Föhn* must occur in some localities under certain meteorological conditions. Drygalski has called attention to the

importance of *Föhn* as a climatic factor in Greenland. Where the heat disengaged by the contraction of the descending air is sufficient to raise its temperature above that of melting ice, its effect is at once apparent, and the fact that the West Coast of Greenland is free from land-ice at and near the sea-level, is attributed mainly to the heat of the *Föhn*. It is evident that, in the middle of winter with a general temperature of $-30°$ C. to $-50°$ C. *Föhn* may prevail without its being able to raise the temperature of the air to that of melting ice. Indeed, it may even raise it above this temperature, but the air will not melt any ice in the open until it has raised its temperature from $-30°$ or $-50°$ up to $0°$ C., and this will take some time, which may be longer than that during which the *Föhn* prevails. In summer in Greenland, the general temperature of the air is above that of melting ice, and the effect of *Föhn* is observed in the *increased* melting of the ice. From the observations of Mr. Bernacchi, there seems to be reason to suppose that the surface of the ice which forms the great barrier does not usually rise to its melting point even in the warmest month, February. Apart from the indications of the thermometer, in Greenland the occurrence of *Föhn* was made most evident in spring and autumn by its producing melting of the ice, which without it did not take place.

"Later in the year, in the middle of August, I visited the upper Engadine, and stayed for some weeks at Pontresina. Here, as elsewhere, the weather was very warm, and I was much struck by observing the same blasts of hot air as I had experienced in Scotland. The general characteristics of the weather were the same, and the temperature of the air in the valley rose nearly as high as it had done at Fort William.

"On the 18th August I went for an excursion on the Morteratsch glacier with a guide. On my remarking the hot puffs of air, which were much more striking on the ice than on the land, he said it was the *Föhn*, of which he considered them a characteristic. The sun and the hot wind were causing an enormous amount of surface melting of the ice, and having a thermometer with me, I took the temperature of the air by whirling at a height of about 1 m. from the ice, and found it $12°\cdot0$ C.; the wet bulb was $5°\cdot0$, so that the vapour tension was $2\cdot3$ mm., the relative humidity 22, and the dew point $-8°\cdot6$ C. The great dryness of the air will be remarked. I then swung the thermometer in a conical path as close to the ice as possible, and the temperature of the air was $10°\cdot0$ C. Being astonished to find this high temperature close to the ice, I put the bulb of the thermometer into a crack in the ice, so as to be below

the level of the surface of the ice, and its temperature only went down to 7·5° C.

"All the temperatures were taken with a mercurial thermometer, which was whirled at the end of a string so that its velocity was about 6 m. per second. It was not protected in any way, so that the temperatures observed with it are not free from a certain error due to radiation and reflection, although it was always shaded from the direct sun. These errors are not usually great with a whirled instrument, and most of my observations have to do with differences of temperatures observed with the same instrument and under similar circumstances. On the glacier the thermometer, when whirled, was not apparently affected by radiation or reflection from the ice, and only very slightly by that from the sun. On land I remarked that the greatest disturbing effect is produced by sunlight reflected from grass. If the thermometer was whirled in the shade of a north wall with a grass field or hill-side close by, the thermometer would be immediately affected to the extent of one or two degrees, according as the sun shone on the grass or was obscured by a cloud. The effect was immediate the moment the sun came out; sunlight reflected from rocks and light-coloured surfaces did not produce the same effect.

"On the 19th August I returned to the glacier. At 11 a.m. in the valley below the glacier I found the temperature of the air 22° C., and the wet bulb 12°·5, whence the vapour tension is 5·0 mm., and the relative humidity 26. In determining the temperature of the air by whirling the thermometer I found variations of as much as 2°. The hot puffs of air made themselves felt most markedly, and showed that the real variations of the temperature of the air were much greater than the thermometer showed. At 1 p.m., on the hill-side, to the west of the tongue of the glacier, and at a height of about 2100 m. above the sea, four good observations of the temperature were made, giving 17°·5, 18°·0, 19°·5, and 19°·0; they are all equally trustworthy, and represent the average temperatures of the air during the minute, or minute and a half, that the thermometer was whirled. The mean of these values, 18°·5 is taken as the temperature of the air. For determining the temperature of the wet bulb, the bulb of the thermometer was wrapped round with one thickness of Swedish filtering paper thoroughly moistened, and the thermometer was whirled as before and until the temperature ceased to fall; it then stood at 9°·5. Still higher up the hill at an altitude of 2250 m., the temperature of the air at 2 p.m. was 18°·5 C. Having returned to the spot where the observations had been made at

1 p.m. the following air temperatures were observed:—between 2.40 and 2.46 p.m., 17°·5, 18°·0, 17°·5, 17°·0, 17°·3, 17°·1; mean, 17°·4; and between 2.50 and 2.54 p.m. 16°·5, 16°·5, 16°·7, and 16°·5; mean, 16°·55. The mean of the two sets is 17°·06. It must be repeated that each of these individual observations is a faithful indication of the average temperature of the air in which the thermometer was whirled, and in so far as its sensibility enabled it to assume the same temperature as the air. From this spot I descended to the glacier and went up it until I got to a position which, judging by the eye, was at the same height as the station just left on the mountain side, and about one kilometre distant from it in a straight line. The weather was rapidly getting colder, the sky being covered with the characteristic *Föhn* cloud. The wind was fresh down the glacier, which made the exposure of the thermometer easy and good. The hot *Föhn* puffs were also very striking. The thermometer was first swung exposed to sun and wind, showing temperatures varying from 10°·5 to 11°·2, the mean being 10°·8 C. Swung in my own shadow, but exposed to the wind, the temperature was 9°·8. The wet bulb was 4°·7, showing a relative humidity of 37. The thermometer was now exposed, both wet and dry, in a horizontal position with the bulb at a distance of about 2 cm. from the ice, on the top of one of the superficial ridges of the glacier, and fully exposed to the wind, though shaded from the sun. The observed temperatures were: dry, 6°·6 C.; wet, 3°·7; relative humidity, 58·5. The exposure of the thermometer was as good as could be desired, and, with the fresh breeze blowing, it was thoroughly ventilated. I was again much struck with the highness of the temperature of the air almost in actual contact with the ice. The observations at 1 m. and 2 cm. from the ice were repeated, giving substantially the same results—at 1 m., dry bulb 10°·2, wet, 5°·1; at 2 cm., dry bulb 6°·8, and wet 3°·2. The hot *Föhn* puffs were more striking on the ice than on the land, owing to the greater difference between their temperature and that of the surrounding air. At 4 p.m. I left the ice and returned to the station of 1 o'clock on the hill-side, and took the temperature at 4.35 p.m.—dry bulb 16°·0, wet 8°·0, relative humidity 24·5. At the station in the valley below the glacier the temperature was at 5.45 p.m., dry bulb 16°·4, wet 11°·8, and relative humidity 56. These observations, besides showing the remarkable conditions of the air over the glacier, indicate the fineness and warmth of the weather which prevailed.

"On the 21st August another series of observations was made at the stations on the land and on the ice. The breeze on the ice was

not so steady or so strong as on the 19th, and about 5 o'clock in the afternoon there was a heavy squall of rain and thunder. The same hot *Föhn* puffs made themselves felt as before, without there being any means of measuring their temperature. Their duration at their maximum temperature was never more than a few seconds, during which but little effect was produced on the thermometer. It occurred to me that the only way of gaining a knowledge of the temperature of these puffs of air would be by comparing the rapidity with which the thermometer moved when exposed to a known difference of temperature, with that observed in the puffs. A number of observations was made with this view, by warming the thermometer and noting its rate of cooling in air of known temperature. The reverse procedure was also followed on the ice. The thermometer was cooled by being laid close to, but not touching, the ice, it was then quickly raised to a height of 1 metre, and its rate of change of temperature observed. In this way it was found that for an initial difference of 4° the thermometer required 10 seconds to rise 1°, for a difference of 3° 12 seconds, and for a difference of 2°·5 16 seconds. These ratios were observed in the open air, and under the circumstances where the hot puffs are observed. Unfortunately, owing to an accident to the thermometer, very little use could be made of them. Where the rate of change of temperature of the thermometer is used to determine the temperature of the air, the movement of the air must be measured or estimated. The observations made on the 19th and 21st August are given in Table XXIV.

"For comparison with the temperatures on the ice on the 19th, the mean of the observations at the land station at 2.45 and 4.35 p.m. is taken, and on the ice the mean of the observations at 3.20 and 3.55 p.m. The altitudes of the two stations were as nearly as possible identical, and they were not more than 1 kilometre distant from each other. Considering the temperatures at a height of 1 m., there is a difference of 6°·5 between the land and the ice. The difference of vapour tension, 0·2 mm., is insignificant, and shows that substantially the air is the same. The dew point in both cases is several degrees below 0°, so that, on the air coming in contact with the ice, there would be evaporation from the latter. The evaporating power of the air may be represented by the difference between the tension of saturation and the actual vapour tension. It is very great on land, being 10·75 mm. at 16°·53 C., and it would rapidly evaporate water having that temperature. On coming in contact, however, with ice, the air actually in contact, which alone comes under consideration, is first cooled to 0° C., which reduces its saturation tension to

4·6 mm., and the difference is only 1·4 mm. We see, however, that this has been sufficient to increase the absolute humidity of the air in close proximity to the ice. At 1 m. above the ice the air had an average temperature of 10° C.; at 2 cm. from the ice its temperature was as high as 6°·65 C., and the air in actual contact with the ice must have been at 0° C. Many observations have been made of

TABLE XXIV.—TEMPERATURE OBSERVATIONS AT EQUAL ALTITUDES ON THE MORTERATSCH GLACIER, AND ON THE MOUNTAIN WEST OF IT.

	Thermometer.		Diff.	Vapour tension.	Rel. hum.	Dew point.
	Dry.	Wet.				
19th *August*, 1893.	°C.	°C.	°C.	mm.	p.c.	°C.
Land station, 2.45 p.m. . .	17·1	8·6	8·5	3·2	22	−5·0
„ „ 4.35 „ . .	16·0	8·1	7·9	3·2	24	−4·7
Mean . . .	16·55	8·35	8·2	3·2	23	−4·85
Ice station, 3.20 p.m. . .	9·8	4·7	5·2	3·26	36	−4·4
Height 1 metre, 3.55 „ . .	10·2	5·1	5·1	3·55	39	−3·5
Mean . . .	10·0	4·9	5·1	3·40	37·5	−3·95
Ice station, 3.20 p.m. . .	6·7	3·7	3·0	4·2	57	−1·4
Height 0·02 m. 3.55 „ . .	6·6	3·2	4·4	4·0	56	−3·0
Mean . . .	6·65	3·45	3·2	4·1	56·5	−2·2
21st *August*, 1893.						
Land station, 1 p.m. . .	14·5	7·5	7·0	3·5	29	−3·5
„ „ 3.45 „ . .	14·3	8·0	6·3	4·2	35·0	−1·3
Mean . . .	14·4	7·75	6·65	3·8	32	−2·4
Ice station, 2.22 p.m. . .	9·85	5·6	4·25	4·2	47	−1·3
Height 1 metre, 2·54 „ . .	11·0	7·0	4·0	5·1	52	+1·5
Mean . . .	10·43	6·3	4·13	4·6	50	+0·1
Ice station, 2.15 p.m. . .	7·3	4·0	3·3	4·1	54	−1·5
Close to ice, 2.40 „ . .	5·5	3·2	2·3	4·2	65	−0·7
Mean . . .	6·4	3·6	2·8	4·2	59	−1·1

the temperature of the air at different heights above glaciers, and, as might be expected, considerable differences have been observed; but I am not aware that any observations have been made on the air almost but not quite in contact with the ice, as are those which have been made at 2 cm. from the ice. The bulb was perfectly shaded from the sun but freely exposed to the wind, it was also fully ex-

posed to any cold radiations from the ice. There is, therefore, no doubt that 6°·65 was the temperature of the air passing the bulb of the thermometer. The vertical distribution of temperature shown by these figures is remarkable. From a height of 1 m. to within 2 cm. of the ice there is a gradient of 3°·4 per metre; in the remaining 2 cm. there is a gradient at the rate of 33° per metre; and, from various observations and considerations, it is probable that the moderate gradient is continued to within a millimetre of the ice, when it becomes precipitous. It is to be noted that the absolute humidity, as shown by the vapour tension of the air, has increased from 3·4 mm., at 1 m., to 4·1 mm., at 2 cm.; showing that ice is being evaporated and transferred from the glacier to the atmosphere. The wind was blowing freshly down the glacier, and its velocity was measured by noting the time which pieces of paper allowed to drift took to reach the ice, and then pacing the distance. The mean velocity was found to be from 8 to 10 kiloms. per hour.

"The observations made on the 21st and on the 22nd confirmed those of the 19th. The same variability of the air temperature at the land stations was noticed. Between 12.55 and 1.6 p.m. the following temperatures were observed by whirling:—16°·2, 16°·2, 16°·0, 15°·5, 16°·0, 15°·5, 15°·0, 14°·2, 13°·8, 14°·0, 13°·5, 13°·5. These are all good observations, and represent real variations of the temperature, or rather they indicate real variations of greater amount. Taking the mean of the last five observations, we have the temperature of the air 14°·0. The wet bulb was found at 1.15 p.m. to be 7°·5, giving a difference of 6°·5. On the glacier the air felt closer than on the previous occasion. The temperature at 1 m. was 11°·5, and at 2 cm. from the ice 7°·3. The difference 4°·2 is less than on the previous occasion. The wind was much less strong, and yet the temperature close to the ice is higher. The wet bulb under the same circumstances, showed 4°·0. Five minutes later the dry bulb was observed at 1 m. 10°·2 and 9°·4, mean 9°·85. Another observation of the dry bulb at 2 cm. from the ice gave 6°·6. The interval between the bulb and the ice was now reduced to the smallest possible distance, about 2 mm. The wind fell very light, and the thermometer remained at 8°·0, when the wind returned it fell to 5°·8. The axis of the thermometer bulb would be about 5 mm. from the ice, and still the air is nearly 6° warmer than the ice. Another observation in the same conditions gave 5°·5. The wet bulb was now exposed, but it had to be kept about 5 mm. off the ice; it showed 3°·2. At 2.43 p.m. a great volume of warm air came down, and the wet bulb ran up to 4°·5 in three or four seconds. With the

return of the breeze the wet bulb went back to 3°·0. The *Föhn* puffs were now very troublesome. At 2.52 p.m. the wet bulb at 1 m. was 7°·0; the dry bulb showed—at 2.54 p.m., 11°·0; at 2·55 p.m., 13°·5; and at 2.57 p.m., 14°·5. In one puff the thermometer was observed to rise one degree in eight seconds, which would make the true temperature of the air at the moment about 6°·0 higher, or 19°·5.

"At 3.30 P.M. I returned to the land stations, and again found the same variable temperatures. Between 3.35 and 3.45 P.M. the temperature varied between 16°·0 and 13°·5. The following averages were taken:

3.45 p.m.,	dry, 14°·3;	wet, 8°·0;	relative humidity, 35.
4.0 „	„ 14°·0;	„ 8°·5;	„ „ 42·5.

"Taking the first of these and the observations at 1 o'clock, we have for the mean temperature of the air 14°·15, and the wet bulb 7°·75. On the ice we have—

At 1 metre,	dry bulb, 9°·85;	wet, 5°·6, and
At 2 centimetres	„ 7°·3;	„ 4°·0.

"The difference in the temperature of the air at 1 m. is only 4°·3, and that between 1 centimetre and 2 metres above the ice is only 2°·55, while the air at 2 centimetres is 7°·3 warmer than the ice.

"On the 22nd August the observations on the ice were repeated, with very much the same results. The temperature of the air ranged from 9°·0 to 9°·5 at 1 metre, and was 5°·5 at 1 centimetre from the ice.

"The result of the few observations here quoted is to show that the air, which over land has a temperature of 15° to 20°, or higher, in passing over a glacier is cooled to a comparatively slight degree. Although the air appears to be thoroughly mixed by its own motion, very sharp gradients of temperature are produced and maintained. The great and abnormal temperature of the air of the valley is kept up by the heat liberated by the compression accompanying the descent of local streams or striæ of air from high levels. These keep up an extra supply of heat over and above what is supplied by the direct radiation of the sun. The result is that the melting of the glacier in *Föhn* weather greatly exceeds that of even the hottest day of ordinary weather.

"In order to convey a general idea of the climate in the neighbourhood during the period when my observations were made, I subjoin a table of the air temperatures observed at the Pfarrhaus in Pontresina

three times daily, and obligingly supplied to me by Herrn Pfarrer Falliopi.

TABLE XXV.—TEMPERATURE OF THE AIR AT PONTRESINA.

Date.	Temperature of the air observed at					
	7 a.m.		1 p.m.		9 p.m.	
	Temp.	Diff. from mean.	Temp.	Diff. from mean.	Temp.	Diff. from mean.
1893	C°.		C°.		C°.	
August 15	4·7	−2·92	19·2	−1·26	10·0	−1·36
„ 16	5·9	−1·72	20·0	−0·46	10·8	−0·56
„ 17	7·2	−0·42	20·8	+0·34	11·8	+0·44
„ 18	8·2	+0·58	21·8	+1·34	12·8	+1·44
„ 19	8·6	+0·98	21·2	+0·74	12·8	+1·44
„ 20	10·0	+2·38	19·8	−0·66	12·6	+1·24
„ 21	7·6	−0·02	22·2	+1·74	10·2	−1·16
„ 22	8·2	+0·58	20·2	−0·26	10·2	−1·16
„ 23	6·9	−0·72	19·2	−1·26	12·8	+1·44
„ 24	8·9	+1·28	20·2	−0·26	9·6	−1·76
Mean . . .	7·62	..	20·46	..	11·36	..

"In this table, the high temperature on the 18th, 19th, 20th and 21st, is very apparent. The *Föhn* prevailed during all these days.

"On the 23rd August, which was a very warm day, I made a series of observations between Pontresina and the top of the Piz Languard, which is the highest peak on the ridge immediately behind Pontresina, and is very easily accessible. It had been raining heavily in the night, so that in the early morning the air was rather cool; but the following observations, made before starting up the mountain, will show how rapidly the temperature was beginning to rise.

8.0 a.m., dry bulb, 10°·4; wet, 9°·2.
9.10 „ „ 14°·8; „ 11°·4.
10.0 „ „ 17°·0.

"At 10 A.M. I started up the mountain, following the excellent path which leads to the summit.

"In Table XXVI. the temperatures observed at various stations are entered, along with corresponding ones observed in the porch of the Hotel Reseg at Pontresina.

TABLE XXVI.

	Height above sea.	Time.	Temperature On mountain.	Temperature At hotel.	Difference.
	m.		°	°	
Pontresina	1800	10.0	17·0	..	..
	2100	10.50	16·5	19·5	3·0
	2250	11.5	16·5	20·0	3·5
	2370	11.35	16·5	20·5	4·0
	2670	12.0	14·5	20·75	6·25
	2790	12.30	13·3	21·0	7·7
	2970	1.6	14·0	21·5	7·5
	3180	1.30	13·1	22·0	8·9
Summit	3266	2.10	11·0	..	..
	—	2.40	10·5	22·0	11·25

"Excepting in the first interval the rate of fall of temperature between Pontresina and the station on the mountain is less than 1° per hundred metres. At the summit the mean temperature of the dry bulb was 10°·75, and of the wet bulb 6°·45, whence we have the vapour tension 4·5 mm. and the relative humidity 47. The weather was of the same kind as in the valley, abnormally warm, and the air very dry."

Conclusion.—It will be observed that in this chapter no attempt is made to give instructions to the Chemist and Physicist. Here and there a lead in one direction or another is suggested. He must rely on his own knowledge and experimental ability. Questions or problems which excite his curiosity should be worked out in his own way. If, in this way, he answers or solves them to his own satisfaction, it is probable that he has made a genuine addition to knowledge. In all his work it will be useful for him to remember that, primarily, Physics and Chemistry are branches of Natural History.

X.

GEOLOGY.

COMPILED BY W. T. BLANFORD, LL.D. F.R.S.

THERE can be no question as to the geological interest attaching to the regions around the South Pole. Apart from ordinary subjects of geological inquiry, such as the presence and nature of sedimentary and volcanic formations, the occurrence of granitic and schistose crystalline rocks, the relations of the different formations to each other, and the evidence of ancient forms of life afforded by fossils, there are two geological problems connected with the past history of the Antarctic area that are of especial importance. One of these is the climate of Antarctic regions in past times, the other the distribution of sea and land in the Southern Hemisphere at former periods.

There are already some indications that within the Antarctic, as within the Arctic circle, considerably higher temperatures than those now prevailing have existed in the past. Further observations are required to show whether the climate has been comparatively warm during the whole or the greater part of the world's history before the latter portion of the Tertiary era, or whether warm and cold periods have alternated. The most useful information on these questions may be afforded by remains of animals and plants found imbedded in the rocks. The discovery of coal in particular would be of great scientific interest apart from its practical importance, and should any be found, a careful search ought to be made for impressions of plants in the strata associated with the coal, both above and below the coal-seam. Search should also be made in the older strata for the evidence of glacial action afforded by boulder beds; large fragments of rock, sometimes striated, imbedded in a fine matrix would afford such evidence.

The second problem, that of the distribution of sea and land in past times, and of former land connection between the Antarctic area and the Southern continental masses is of great interest, and the solution, if obtained, may not improbably throw light upon the old

question why the great continents terminate to the Southward in points.

There is much probability that the Antarctic continent will prove to be a very ancient continental tract. In this case marine stratified beds may be restricted to the coasts, though, as in other ancient continents, sedimentary rocks of fresh-water or subaërial origin, possibly containing remains of plants and of vertebrate animals, may be largely developed in the interior.

Evidence suggesting land communication in past times between the Antarctic area and the other Southern continents has accumulated greatly during the last thirty or forty years. Perhaps the most remarkable instance is that connected with the distribution of the southern Permo-carboniferous or *Glossopteris* flora. This flora has been long known in South Africa, India and Australia, and recently it has been discovered in South America and in Russia. It was quite distinct from the contemporaneous *Sigillaria* and *Lepidodendron* flora, the upper Palæozoic flora of Northern lands, though a slight admixture of the two has been found in South Africa and South America. That the *Glossopteris* flora travelled Northwards at the close of the Palæozoic era and replaced the *Sigillaria* flora appears evident from the fact that the former so closely resembles the Mesozoic flora of Europe as to have been for a long time regarded as Mesozoic by palæobotanists. Curiously enough, there is much to suggest that this *Glossopteris* flora came originally from the South to Africa, America, Australia and India, for it was preceded in three of those areas by an earlier flora of the Northern Palæozoic type and the line of division between the two floras is marked by a bed containing boulders transported by ice, and affording evidence of a phase of low temperature. It is not an unreasonable inference that this *Glossopteris* flora, which is singularly poor in species, is the offspring of a cold climate vegetation, that it had its origin in the Antarctic continental area and was driven Northward towards the equator along tracts of land now beneath the ocean, during the prevalence of a period of cold similar to the glacial epoch of Pleistocene times, until it finally reached and crossed the equator and replaced the old Palæozoic flora of our coal-measures. Should any traces of the *Glossopteris* flora be found in the Palæozoic rocks of the Antarctic area, especially if there be reason for believing that these rocks are more ancient than the *Glossopteris* beds of Australia and South Africa, the hypothesis above suggested will be strongly supported.

But if the *Glossopteris* flora came from Antarctic regions and spread over the world, may not other faunas and floras have had the

same origin and a similar history? We know nothing of the origin of the placental Mammals which took possession of the earth's surface in Eocene times, nor whence Acanthopterygian fishes and Angiospermous plants, now the dominant forms throughout the world, suddenly appeared in great numbers in the middle of the Cretaceous epóch. It is well now and then to remember how many great geological problems are as yet unsolved, and that no clue should be neglected which may lead to their solution.

The *Glossopteris* flora is by no means the only indication of connection between the Southern continents through the Antarctic area. One remarkable fact is the discovery in South America of one living genus *Cœnolestes*, and of several extinct forms (Epanorthidæ, &c.) belonging to the Diprotodont marsupials, peculiar with this exception to Australia. No representative of this group, living or fossil, has been met with in the Northern Hemisphere, all fossil marsupials there occuring are Polyprotodont. The curious horned tortoise *Miolania* has been found fossil in both Australia and Patagonia, and several other cases of relationship in the Tertiary faunas of the two areas are reported. Another interesting fact is the occurrence in Madagascar, where a remnant of the old African fauna appears to have taken refuge, of land-tortoises and frogs belonging to South American types. There is a somewhat similar connection, though by means of different families from those occurring in Madagascar, between the Batrachia and tortoises of Australia and South America.

It is quite true that no single instance of those cited affords conclusive evidence of land-connection with the Antarctic region, but the cumulative evidence, especially in the case of Mammals and Batrachia, distinctly proves land-connection of some kind and appears to indicate a possibility that in upper Mesozoic and Tertiary times, as in upper Palæozoic, communication by land existed between the continental masses of the Southern Hemisphere and the Antarctic continent. In view of the probability that the greater portion of the Antarctic land, whether continent or archipelago, is shielded from observation by a sheet of ice, it is to be feared that but few observations on its geology will be practicable, but it is essential to point out that, provided only portions of the surface are accessible, the collection of a few fossils from any sedimentary rocks exposed may furnish the solution to one of the questions involved, and that these questions are sufficiently numerous to affect a great variety of forms of life.

The following instructions are taken for the most part from those drawn up by Charles Darwin for the Admiralty 'Manual of Scientific

Enquiry,' and revised by Sir A. Geikie. A few additions have been made from the geological portion of 'Hints to Travellers,' issued by the Royal Geographical Society. It would be well for anyone who has no previous acquaintance with geology, and who is likely to have an opportunity of making observations in the Antarctic regions, to study the 'General Instructions for Observations in Geology' written by Sir A. Ramsay in the 'Arctic Manual' of 1875.

A person embarked on a naval expedition, who wishes to attend to geology, is placed in a position in some respects highly advantageous, and in others as much to the contrary. He can hardly expect, during his comparatively short visits at one place, to map out the area and sequence of widely extended formations, and the most important inferences of geology must ever depend on this having been carefully executed; he must generally confine himself to isolated sections and small areas, in which, however, without doubt, many interesting facts may be collected. On the other hand, he is admirably situated for studying the still active causes of those changes, which, accumulated during long-continued ages, it is the object of geology to record and explain. He is borne on the ocean, from which most sedimentary formations have been deposited. During the soundings which are so frequently carried on, he is excellently placed for studying the nature of the bottom, and the distribution of the living organisms and dead remains strewed over it. Again, on sea-shores, he can watch the breakers slowly eating into the coast cliffs, and he can examine their action under various circumstances. In the wasting operations of air, rain, frost, rivers, waves, and the other denuding agents on the surface of the globe, he sees the processes which have planed down whole continents, levelled mountain ranges, hollowed out great valleys, and exposed over wide areas rocks which must have been formed or modified under the enormous pressure of an overlying mass of rock since removed. Again, as almost every active volcano is situated close to, or within a few leagues of the sea, he is admirably situated for investigating volcanic phenomena, which, in their striking aspect and simplicity, are well adapted to encourage him in his studies.

The mere collecting of fragments of rock, without some detailed observations on the district whence they are brought, is of comparatively little value. The simple statement that one part of a coast consists of granite, and another of sandstone or clay-slate, can hardly be considered of much service to geology; it may be remarked, how-

ever, that the crystalline rocks of different areas present characteristic peculiarities, and a collection of such rocks in a district so new to us as the Antarctic region, can scarcely fail to afford useful material to the petrologist. Still more important is the collection of organic remains, on which subject some remarks will presently be made. The observer ought to collect suites of rock specimens and fossils, with the intention of himself subsequently drawing up an account of the structure and succession of the rocks in the countries visited. For this end, he can hardly collect too copiously, for errors in the naming of the rocks may thus be corrected, and the careful comparison of such specimens will often reveal to him curious relations which at the time he did not suspect. He must record, on the spot, such observations as may give a permanent interest to the specimens, accompanying them by sketches or photographs when useful, and *not trusting to memory.*

In order to make observations of value, some reading and much careful thought are necessary; but perhaps no science requires so little preparatory study as geology, and none so readily yields, especially in foreign countries, new and striking points of interest. Some of the highest problems in geology wait on the observer in distant regions for exploration—such as, whether the successive formations, as judged of by the character of their fossil remains, correspond in distant parts of the world to those of Europe and North America, or whether some of them may not correspond to intervals of time, during which sedimentary beds were not accumulated in the latter regions, or, having been accumulated there, have been subsequently destroyed; and again, whether the lowest formations everywhere are the same with those in which the most ancient forms of life have been recognised in the countries best known to geologists. These and many other wide views in the history of the world are open to any one who, applying thought and labour to his subject, has the good fortune to geologise in countries little frequented.

The appearances presented by the different forms of stratification (that is, the original planes of deposition) may be soon learnt in the field; though no doubt the beginner would be aided by the diagrams given in many elementary works, or in the 'Arctic Manual.'

Outfit.—The essential articles of a geologist's outfit are neither numerous nor cumbrous. A very large proportion of the known geology of the world has been made out with no more elaborate appliances than a hammer, a pocket compass with a small index to serve as a clinometer, a pocket lens, a note-book and a pencil. No

scientific observer has to depend more on his own knowledge and faculty for observation, and less on instrumental appliances, than a geologist.

The best hammer for general purposes should weigh from 12 to 24 oz. and should have a square flat end, and a straight cutting end —the latter may be horizontal or vertical, according to fancy. The ends should be of steel, not too highly tempered. The hole for the handle should be as large as possible (with a small hole the handles are so weak as to be liable to break), and the handle should be secured in the hole by a wooden wedge, and an iron one driven into and across the wooden one. It is advisable to take a few spare ash handles. It is as well to have more than one hammer in case of loss; and for fossil collecting, at least one heavy hammer with one end fashioned to serve as a pick, three or four cold chisels of various sizes, and a short crowbar will be found useful.

A very good pocket compass is made in the shape and size of a watch with a clinometer arm. The use of the clinometer is for measuring the angle of dip in rocks. In an uneven country it is not easy without the clinometer to judge which is the line of greatest inclination of a stratum; and it is always more satisfactory to observe the angle than to estimate it. A flat piece of rock representing the general slope can usually be found, and by placing a note-book on it the measurement can be facilitated. It is best to determine and record the "strike"—that is, the direction of a horizontal line on the surface of the stratum—first; then at right angles to this line measure the "dip," or angle of inclination, and note its direction by compass, correcting for variation. The lie of a bed is fixed if the *direction* and *amount* of the dip be recorded—the strike being always at right angles to the dip. In a country where slaty cleavage occurs, precautions are needed, which will be noticed as we proceed. As a rule, except with very low angles of dip, the variation in the inclination of the rocks themselves exceeds the limits of error of the instrument. A little care, however, is necessary in taking dips; for the apparent dip seen in a section, such as is often exposed in a cliff, may differ widely from the true dip, which will only be shown if the section runs at right angles to the strike of the beds. Dips seen on the sides of hills at a distance are but rarely correct, for the same reason.

A prismatic compass and an aneroid are frequently of great service: the former to determine the position on the map, if one exists, and to aid in making a rough map, if there be none; and the latter to estimate roughly the heights on the road travelled, especially

in mountainous countries, and also to measure the thickness of horizontal beds. A good aneroid gives sufficiently accurate determinations of height for a rough but adequate geological section across any country if the distances are known.

Abney's pocket level is a portable and useful instrument. An observer, having previously ascertained the exact height of his eye when standing upright, can measure the altitude of any point with some degree of accuracy; he has only to mark by the level a recognisable stone or plant, and then to walk to it, repeat the process, and keep an account how many times the levelling has been repeated in ascending to the point the height of which he wishes to ascertain.

Rules for Collecting.—A few cautions may be here inserted on the method of collecting. Every single specimen ought to be numbered with a printed number (*those which can be read upside down having a stop after them*), and a book kept exclusively for their entry. As the value of many specimens entirely depends on the stratum or locality whence they were procured being known, it is highly necessary that every specimen collected should be ticketed on the same day. If this be not done, the collector will never in after years feel sure that his tickets and references are correct.

Labels should not be put up in contact with the rock-fragments themselves, or they will be worn by sharp edges and become illegible, if not rubbed to fragments. Always wrap each specimen in paper, or some substitute, then add the ticket or label, and then an outer covering. The label, if nothing else be written, should always record the locality distinctly written, either in ink or by a hard black pencil, or better still, a blue indelible pencil.

Pill boxes are useful for packing fossils. Masses of clay or any soft rock may be brought home if small fossil shells are abundant in them. A convenient size for rock specimens is 4 inches to 4½ inches long by 3 inches broad, and one inch to half an inch thick. To save subsequent trouble it will be found convenient to pack separately, and mark sets of specimens which come from different localities. These details may appear trifling; but few are aware of the labour of opening and arranging a large collection, and such have seldom been brought home without some error and confusion having crept in; whenever it is practicable, a collection should be unpacked and arranged by those who packed it originally.

In collecting fossils, it is useless to take many specimens of one kind unless carriage is exceptionally plentiful. Two or three good examples of each kind are usually sufficient, but as many kinds as possible should be collected. Great care is necessary that all the

specimens from one bed be kept distinct from those from another stratum, even if the bed be thin and the fossils in the two beds chiefly the same species. If there be a series of beds, one above the other, all containing fossils, measure the thickness roughly, draw a sketch-section in your note-book, apply a letter or a number to each bed in succession on the sketch, and label the fossils from that bed with the same letter or number.

Remains of Vertebrata, especially of mammals, birds and reptiles, are of great interest; but it is useless to collect fragments of bones without terminations. Skulls are much more important than other bones, and even single teeth are well worth collecting. After skulls, vertebræ are the most useful parts of the skeleton, then the limb bones. If complete skeletons are found, they are usually worth some trouble in transporting. If fossil bones are found abundantly in any locality, and the traveller has no sufficient means of transport, he will do well to carry away a few skulls, or even teeth, and carefully note the locality for the benefit of future geologists and explorers. The soil of limestone caverns, and especially the more or less consolidated loam, rubble, clay, or sand beneath the flooring of stalagmite, if it can be examined, should always be searched for bones, and also for indications of man or his works.

Fossil shells are of great value and importance. In some cases only casts of these can be found, but even these should be carefully collected. If in clay, and fragile, they should be wrapped first in tissue paper, then in cotton-wool, and then placed in chip-boxes or in empty provision-tins. The importance of fossil plants and the light which they may be expected to throw on climate and on the relations of the Antarctic to other land areas in past times have already been mentioned. If impressions of leaves or of fronds of ferns are met with, care should be taken to obtain specimens as nearly complete as possible, and for this purpose slabs of considerable size may require to be excavated. Beds containing plant remains are often soft or friable, and much care is needed in digging out the specimens, in transporting and in packing them, as in the case of fragile shells. Fragments of fossil wood should be preserved, or sections of stems, if any be found, and remains of fruits or seeds should be especially looked for.

Methods for Observing.—To a person not familiar with geological inquiry, who has the privilege of landing on a new coast, probably the simplest way of setting to work is for him to imagine a great trench cut across the country in a straight line, and that he has to describe the position (that is, the direction of the "strike" and angle

of the "dip") and nature of the different strata or masses of rock on either side. As, however, he has not this trench or section before him, he must observe the dip and nature of the rocks on the surface, and take advantage of every bank or cliff where the land is broken, always carrying the beds and masses in his mind's eye to his imaginary section. In every case this section ought to be laid down on paper, on as nearly as possible the real proportional scale; copious notes should be made, and a large suite of specimens collected for *the observer's own* future examination. The habit of making even in the rudest manner sectional diagrams is of great importance, and ought never to be omitted; it often shows the observer palpably, and before it is too late (a grief to which every sea-voyager is particularly liable), where his knowledge is defective. Partly for the same reason, and partly from never knowing, when first examining a district, what points will turn out the most important, he ought to acquire the habit of writing very copious notes, not all for publication, but as a guide for himself.

It is always a good plan to climb commanding peaks; the general direction of beds, obscure from the lower ground, not unfrequently becomes much clearer when they are seen from above.

When time does not permit of a section across the country being examined, or when for any reason, the land surface in general is not accessible, attention should be paid to such cliffs as exist, and to the sections exposed upon them. Cliffs may often be photographed, and the photograph, if not taken from too great a distance, will serve to show some of the relations of the beds exposed, but the photograph, however good, should be supplemented by notes and sketches, and by a record of the true dip of the strata.

In small islands, a section from side to side should be made, and here again photographs will afford valuable aid in preserving a record of the geology. In all cases the position of fossiliferous beds, if any be found, should be carefully noted.

The various formations that compose the crust of the earth may be divided into (*a*) sedimentary and (*b*) crystalline; and the crystalline rocks may be either igneous or schistose. To some extent all these different classes of formations occasionally pass into each other; sedimentary beds may become cleaved and crystallised; minerals may develop in them, until they become foliated, or composed of layers of different minerals such as quartz, felspar, mica, or hornblende, whilst rocks that are evidently of igneous origin, and injected as veins or dykes or irregular masses amongst other strata, pass into granitic forms, and granite often takes on the character of gneiss, which is in

fact a foliated form of granite, with the constituent minerals ar in layers. Nevertheless, it is generally easy to discriminat glance between ordinary sedimentary strata, volcanic rocks, w intrusive or eruptive, granitic rocks, and schistose formations i ing gneiss, and in all sections the occurrence of these different of rocks must be noted.

One of the commonest difficulties in ascertaining the bedd rocks is caused by cleavage, which is especially seen in slate. rock is found to be easily fissile, observation will show wheth direction of the cleavage is the same as that of the bedding, w is usually easy to recognise, especially on a weathered surface, occurrence of stratified bands differing in mineral character, in or in resistance to the action of atmospheric erosion. The r of cleavage planes to the stratification should be carefully note also to the general outline of the country, especially to the di of hill ranges.

Jointing is another feature of rocks that may occasionally m It consists of parallel joints or cracks, frequently in more th direction, and often rendered conspicuous by weathering, as the decompose more readily along the joints than elsewhere, an spicuous cracks or fissures are produced. The bedding m distinguished by the same features as those already noticed remarks on cleavage. Jointing often affects hard solid rocks, s sandstones, limestones, basalt and granite.

Wherever a section is made, specimens of every rock ob should be collected and carefully labelled, so that the form exposed in the section may be subsequently identified. Spe should be taken from rocks in place, not from loose fragmen some care is necessary to select portions of the rock that ha undergone extensive alteration from exposure. One surface a of every specimen taken should be a clean fracture of appa unaltered rock. By means of the specimens any difficulty in mining the name to be applied to a rock can be removed.

Volcanic rocks and glacial formations receive separate With granitic, gneissic, and schistose rocks little can be done to note the direction of any foliation that may exist; to as whether the strike and dips are approximately constant; a collect specimens of the different rocks exposed. Where the area examined consists of gneiss and schist, detailed sections, made by experienced geologists, are not worth the great amo trouble they involve.

In case of the rocks being completely concealed by ice,

information as to the ground covered may be obtained from stones and boulders imbedded in the ice itself. This may be best seen in the neighbourhood of the spot where glaciers melt or on the edges of an ice sheet. If stones are borne on the surface of glacier ice, this probably indicates the presence of areas of naked rock (known in Greenland as *nunataks*) rising above the surface of the ice, and it is desirable that these should be examined. All that can be learned from stones imbedded in the ice of a glacier or ice sheet, carried on the surface or imbedded in the body of an iceberg, or dredged from the bottom of the sea after having been deposited there by the melting of ice, can only give imperfect or general knowledge of the geology of the country from which the ice has borne the fragments; but even this information is better than none, and all such occurrences of rock fragments in or above ice, or dredged from the sea bottom, should be recorded, and specimens preserved.

Elevation and Subsidence of the Land.—One question will usually present itself to almost every geological observer, and that is, whether any coast he may be landing upon affords evidence of elevation or depression. In the former case, beds of rolled pebbles or of marine shells, similar to those now living on the shore, may be found at some elevation above high-water mark. Very often the commonest molluscs in raised beds are the kinds occurring in estuaries, which are different from those inhabiting an open coast. Caution is necessary, however, that heaps of shells made by man, or isolated specimens transported by animals (birds or hermit-crabs), or by the wind, be not mistaken for evidence of raised beds.

To distinguish the shells transported by animals from those uplifted by terrestrial movement, the following characters may be used: whether the shells seem to have long lain dead under water, as indicated by barnacles, serpulæ, corallines adhering to their *insides;* whether the shells, either from not being full grown or from their kind, are too small for food; remembering that certain shells, as mussels, may be unintentionally transported by man or other animals in their young state while adhering to larger shells; and lastly, whether all the specimens have the same appearance of antiquity. The very best evidence is afforded by barnacles and boring shells being found attached to or buried in the rock in the same positions in which they had lived; these may be sometimes found by removing the earth or birds'-dung covering points of rock.

If the shore is steep, terraces on the hill-sides may mark the levels at which the sea remained in past times, but some care is necessary not to mistake outcrops of hard beds for terraces. On such

coasts terraces rising like steps, one above another, often occur. Their outline and composition should be studied, diagrams made of them, and their height measured at many and distant parts of the coast. There is reason to believe that in some instances such terraces range for surprisingly long distances at the same height. Where several occur on opposite sides of a valley, a spirit-level is almost indispensable in order to recognise the corresponding stages.

The evidence of depression, on the other hand, unless there are buildings or trees partly sunk in the water, is much less readily obtained, and neither trees nor buildings are available as evidence, unless the depression be of comparatively recent date. The best proof is the form of the coast. If inlets of moderate breadth occur, with numerous branches, a little examination will frequently show whether such inlets are valleys of subaërial erosion, as is not unfrequently the case, that have been depressed below the sea. In higher latitudes, care must be taken to distinguish the features of glacier valleys, like the friths and lochs of Scotland, and the fiords of Norway, from those valleys of subaërial erosion that have recently undergone subsidence. It is highly probable, even in the case of glacier valleys, that they were originally formed by fresh-water denudation, and that they have been depressed, though their features may have been modified by the action of ice.

In conclusion, it may be re-urged that the geologist must bear in mind that *to collect specimens* is the least, though a very important, part of his labour. If he collects *fossils* he can hardly go wrong; if he be so fortunate as to find the *bones of any of the higher animals*, he will, in all probability, make an important discovery. Let him, however, remember that he will add greatly to the value of his fossils by *labelling* every single specimen, by never *mingling* those from *two formations*, and by describing the *succession of the strata* whence they are disinterred.

XI.

INSTRUCTIONS ON THE OBSERVATIONS WHICH SHOULD BE MADE IN CASE VOLCANOES OR EVIDENCES OF VOLCANIC ACTION SHOULD BE MET WITH.

By J. W. Judd, C.B. LL.D. F.R.S.

Should any volcanic rocks be met with, the following suggestions may aid the observer in directing his attention to the most important points in connection with them.

I. *If the rocks have a fresh appearance, and are of comparatively recent origin*, the following circumstances concerning them should be particularly noted:—

A. Lava-Streams. Concerning these should be recorded—

a. Dimensions. Distance from point of origin; breadth at various parts of course; thickness, so far as it can be determined, and especially as affected by the accidents which the current meets with in its flow.

b. Slope over which they flow. This should be measured at various points with a clinometer if possible, and, at points where the inclination suddenly changes, any variations in the dimensions or other characters of the current should be carefully noted.

c. Surfaces of lavas. Attention should be paid to the features presented by these, whether smooth and "ropy," or bristling and scoriaceous.

d. Texture. Note specially if the rock of the current be porphyritic, compact, globular, concretionary, pumiceous, glassy, sphærulitic, or coarsely crystalline. If the rock presents ribboned or banded structures, observe, if possible, the relations of these to the direction of flow of the stream. When the rock exhibits transitions from one texture to another, collect series of specimens, illustrating the gradation. Note especially changes between the surface and interior of current, or those taking place at different points of its course.

e. Structure. All peculiarities of jointed, and especially of columnar, structures are worthy of being recorded. Note the features presented by the upper and lower part of the current, and any changes in its course; also if columns be divided by transverse joints, and the features presented by these, etc.

f. Chemical and mineralogical constitution. If the appearance of the rock does not suggest at once the class to which it belongs, and the component minerals cannot be detected with a lens, recourse may sometimes be had to a determination (even roughly) of its specific gravity.

g. Sometimes lavas contain large masses of *included minerals*, either crystallised around cavities, or resulting from the alteration of ejected blocks. These are very interesting, and should be carefully collected.

h. Cavities, or air-bubbles, in comparatively recent lavas, are frequently found coated with beautifully crystallised minerals. And when the rocks are of older date, the similar cavities may be lined or filled with crystals of zeolites and other minerals.

B. Nature of Beds lying between Lava-Currents.

These are of the utmost interest and value to the geologist, but unfortunately the ordinary mode of weathering of volcanic rocks is such as greatly to obscure the interbedded deposits by a talus of fallen fragments. The best opportunities for their study are afforded by sea-cliffs, and deep ravines or river-gorges, which should therefore be carefully examined. In such situations we may expect to find—

a. Burnt soils ("Laterites" of Lyell), usually of a brick-red colour, and affording various evidences of their modes of origin.

b. Coal- or Lignite-seams. These are very frequently observed. Note if they rest upon an "underclay" (an old soil with roots), and if they contain wood, leaves, or other plant-remains, with recognisable structure.

c. Ash-beds. These are sometimes composed of such impalpable dust as to constitute a matrix in which delicate leaves, shells and even insect remains are exquisitely preserved. The collection of every trace of organic bodies is of the greatest importance.

d. Stratified tuffs. Note especially the degree and nature of their stratification; also whether they are loose or indurated. They may contain shells and plants of terrestrial or marine origin. Record the elevations at which the latter are found.

e. Gravels or other deposits. Note their characters and materials, and, if possible, define their mode of origin.

C. Cones, Craters, etc. Wherever the lavas present a fresh appearance, an attempt should be made to trace them up to their points of origin.

a. If any great *volcanic mountain* be met with, all details concerning the lava-streams, fragmentary matters, and dykes of which it is built up will be of great interest. Failing these, however, sketches of the mountain, and of specially interesting portions of it, accompanied by such rock-specimens as can be obtained, will be of service to geologists.

b. Cinder-cones on the flanks of a volcano, or scattered around it, should be examined and sketched. Note if they originate streams of lava.

c. The craters, both of volcanic mountains and of cinder-cones, should be examined. Note if they are breached by lava-streams, or contain bosses of lava in their interiors, or buttress-like masses adhering to their sides.

d. Note specially the *arrangement* of the smaller and larger cones in respect to one another. Furnish, if possible, plans to illustrate this point, or failing these, as many general outline sketches as possible.

e. In and around the craters look for *fumaroles,* and, if possible, record the nature of the gases evolved from them. Collect the interesting minerals found in the crusts which are deposited round the vents, and in the rocks traversed by the vapours and gases.

f. Hot springs, geysers, etc., often occur in the vicinity of active or recently extinct volcanoes. These the observer should be on the look-out for (their vapours often render them conspicuous at great distances), and their phenomena should be carefully recorded. Specimens of hot and mineral water should be sealed up in bottles, and brought home for examination and analysis.

g. Deposits of siliceous sinter, travertine, etc. These, besides yielding interesting varieties of minerals and illustrations of their mode of formation, often contain incrusted or mineralised remains of plants or animals, which may be of great interest.

h. On the flanks of volcanoes ejected blocks of limestone and other rocks, often much altered, are found. These sometimes contain interesting minerals, and should be very carefully collected.

(In the event of the observer being so fortunate as actually to witness an eruption of a volcano, every detail that he can supply may be of scientific value. Especially should he note the appearances presented by the ascending column of vapour and fragmentary materials issuing from the crater, the height to which this rises, the nature, sequence, and rate of the explosions to which it is due, and

the sounds which accompany them. All earthquake shocks and tremblings of the ground should of course be recorded. If lava-streams are seen flowing, their rate of motion and attendant phenomena should be carefully noted.)

II. *If the volcanic rocks have evidently been subjected to great denudation*, the following points should be more particularly attended to:—

A. The composition, textures, and various structures of the different lavas should be carefully observed, and all zeolites or other minerals in their included cavities collected.

B. If the igneous rocks be found alternating with sedimentary ones, all fossil remains which can be obtained from the latter will have a *double* value, as throwing light on the age both of the aqueous and the volcanic rocks. But it will be especially necessary to notice whether the igneous masses be *interbedded* and *contemporaneous* with the aqueous deposits, or *intrusive* and *subsequent* to them. In seeking to determine this point, it must be borne in mind that—

Lava streams have slaggy or scoriaceous upper and under surfaces, and that they only alter the rocks upon which they rest.

Intrusive sheets, on the other hand, are seldom scoriaceous, and alter the rocks both below and *also above* them. They moreover occasionally cross the lines of bedding of the strata, and send off dykes or veins into them.

C. If possible, the lavas of the district should be traced up to central masses of *intrusive rocks*. The forms assumed by these in weathering should be sketched, and specimens illustrating the different characters which they assume and the minerals they contain collected.

D. All the phenomena of metamorphism exhibited by the stratified rocks in the vicinity of intrusive masses, whether dykes, sheets, or bosses, should be looked for, and their nature and extent recorded. In connection with this subject, it should be remembered that very many interesting minerals are developed near the junction of igneous rocks with those which they traverse. Series of rock-specimens illustrative of a gradual change in characters will be very valuable.

E. If masses of tuffs and volcanic agglomerates be met with, they will frequently be found to contain crystals (more or less perfect) of various volcanic minerals. Not unfrequently they also yield fragments of rock which have been ejected from a volcanic vent. These,

if of aqueous origin, may be searched for fossils ; in all cases, however, they frequently exhibit signs of having undergone changes by the action of heat, acid vapours, etc. upon them. Such masses should be broken up and carefully examined, for they frequently enclose in their cavities some of the most beautifully crystallised varieties known to the mineralogist.

The general instructions as to the instruments best adapted for the purpose of the geological observer, and of the tools used for obtaining rock specimens and minerals, are of course equally applicable to the student of vulcanology. But as igneous rocks are in many cases especially liable to change by weathering, the greatest efforts should be made to obtain specimens as fresh and little altered as possible. In those cases, however, where the rock assumes any peculiar features in consequence of meteoric actions upon it, specimens both of the unaltered and of the altered rock are desirable.

Works of reference on Vulcanology, useful to the traveller :—

G. Poulett Scrope, Volcanoes. 2nd edition. 1872. Longman & Co.

J. W. Judd, Volcanoes : what they are, and what they teach. 1881. Kegan Paul Trübner & Co.

T. G. Bonney, Volcanoes : their Structure and their Significance. 1899. John Murray.

XII.

ICE OBSERVATIONS.

By Professor J. W. Gregory. D.Sc. F.R.S. F.G.S. Assisted by Professor T. G. Bonney, D.Sc. LL.D. F.R.S. F.G.S.*

Members of the Expedition will have ample opportunities for the observation of Antarctic ice, but, that the observations may be scientifically useful, they must be systematic, and directed along certain definite lines. The following notes suggest lines of enquiry and a few explanations as to their objects.

The great ice fields of the world may be divided into three groups. (1) Land ice—fields of snow and sheets of ice, and their tributary glaciers, which act as ice rivers, discharging the surplus snowfall from the collecting grounds to lower levels. (2) Icebergs—blocks of ice which have been detached from glaciers where they reach the sea or lakes. (3) Ice floes—comparatively thin sheets which have been formed in circumpolar regions by the freezing of the sea.

In the Antarctic regions representatives of each group will be found, and probably will be developed on a greater scale than in any other part of the globe. But the study of Antarctic ice is desirable, not only from its local geographical importance, but also from the evidence it may yield as to the conditions of the period when some form of ice agent deposited a vast sheet of clay, sand and gravel over much of North-western Europe, including most of the British Isles, and over Canada and the northern part of the United States.

There has been a prolonged controversy as to the mode of formation of these deposits, but the main question is now reduced to the alternatives, (1) that vast continuous sheets of ice covered most of Northern Europe and America, just as its ice-cap does Greenland; or, that there was a series of local glacial centres, beyond the limits

* As Professor Gregory was obliged to return to Australia before quite completing these notes, he posted the manuscript to me, with the request that I would revise it, adding anything which I thought desirable, and see it through the press. I have accordingly made a few verbal alterations and added an occasional sentence or clause.—T. G. B.

of which material was distributed by icebergs and icefloes. For instance, boulders of rocks from Southern Norway are found on the Eastern coast of England. That they were carried there by ice is now universally admitted, but it is still disputed whether these rocks were transported across the North Sea by floating ice or by a vast ice-sheet which completely filled the North Sea basin. No evidence in support of the latter hypothesis is given by Arctic ice, but the great Antarctic ice barrier may conceivably be doing what some geologists assure us that the Scandinavian ice-sheet did in "the Great Ice Age," and what other geologists tell us is impossible.

Similarly, the study of Antarctic land ice may yield valuable assistance in explaining the origin of the old "glacial drifts." Land ice was first studied in Switzerland, where the existing glaciers show only a limited range of action, and the study of Arctic glaciers at first concentrated attention upon the Swiss glacier type; for the differences between them were overlooked, until trained experts, such as Chamberlin and Salisbury from America, and von Drygalski from Germany, studied the Greenland glaciers. Their descriptions of glacial structures, not exhibited in Switzerland, have enabled a great advance to be made in this branch of geology.

I. Sea Ice and Icebergs.

1. *Icebergs and Floebergs.*—The characteristic Antarctic icebergs are of the flat-topped variety, which in the Arctic regions have been called floebergs, from the belief that they were formed as floes, which gradually increased in thickness by the freezing of layer after layer to the under side of the floe. This question is still open. It can be tested by determining, in the case of similar Antarctic floebergs, the amount of salt in different layers of the berg, the presence or absence of marine organisms (such as diatoms) along porous layers, and the extent to which such marine materials can rise into the berg by capillary action.

2. *Layers or Bands of Clay, Stone, etc.*—If these are present in a berg it has probably been formed from land ice. The height above sea-water to which such bands rise, and of the berg, should both be noted.

3. *Included Rocks.*—The most important information to be obtained from icebergs is to be got by collecting specimens of the rocks and pebbles occurring in them. For rock samples, 4½ in. by 3 in. by

1½ in. is a convenient size.* In the case of boulders, note should be taken as to whether their surfaces are scratched, grooved or polished.

Blocks of sandstones, limestones and clays, should be carefully searched for fossils, for which purpose, whenever possible, the whole of the boulder should be broken up. One specimen of each such kind of rock present should be collected, and a note taken of the relative number and size of the different kinds.

4. *Berg Forms.*—Some idea as to the age of bergs can be obtained from their forms. The bergs may be assumed to begin, in the great majority of cases, as fairly flat-topped blocks of land ice, and, as they float away from their place of origin, they are worn into peaks and pinnacles. Information should therefore be collected as to the distribution of flat-topped and pinnacled bergs.

5. In the case of *stratified icebergs*, the thickness and texture of the different layers should be noted, and the general average texture of the berg above sea level. This information enables an estimate to be made as to the total thickness of the icebergs, which cannot be directly determined unless they are aground, when soundings beside them show their full depth. A stratified appearance may be due to either of two causes—(*a*) the inclusion of layers of clay, grit and stone, which are generally restricted to the lower part of the glacier, seldom exceeding, according to Chamberlin, about seventy-five feet in the Greenland glacier (double that amount being a possible maximum), with clean ice above; or (*b*), an alternation of layers of blue (solid) and white (more porous) ice, which would probably imply little more than that the mass had come from a large glacier.

6. *Floe Ice.*

(1) The thickness of ice formed in a single season, the rate of its increase in thickness, and the maximum thickness † of floe ice met with should all be noted.

(2) The extent to which newly formed thin sheets of ice are

* As it may sometimes be practically impossible, owing to difficulties of carriage, to bring away specimens of this size, it may be well to remark that a fragment, little more than a cubic inch in volume, may be quite sufficient to determine the species of a rock; provided always, the sample be carefully selected to show the average character of the rock, i.e. it must represent the least decomposed part, be free from veins or adventitious minerals, but should show any mineral banding, like stratification, if such there be.—T. G. B.

† The maximum thickness of the ice in the North Polar Sea observed by Nansen during the drift of the *Fram*, from April 10, 1894, to Feb. 6, 1895, just exceeded nine feet; but it attains to a greater thickness by packing of the floe.—'Farthest North,' vol. i. pp. 404–406.

flexible should be observed, both by watching them as they bend above the waves, and by experiments. The structure of such flexible ice sheets should be carefully observed, taking special note whether the ice be compact or porous, whether the ice-crystals in it are all parallel, or whether the sheet consists of a complex of irregularly arranged grains.

Experiments should be made to test the weight required to bend a measured lath of such ice, and of the extent to which the lath will bend without breaking.

(3) The formation of floe ice and its relation to the temperature should be noted, and the observations on its composition and that of the sea-water, which are described in the 'Arctic Manual' (pp. 638–9), should be continued. The changes, if any, in the floe ice as the winter proceeds should be observed; also, how far the presence or absence of salt in it depends on the temperature at which it is formed, and whether, as the spring approaches, the disintegration of the ice is aided by some kind of endosmosis of the sea-water.

II. Coast Ice.

In reference to the action of coast ice, data should be collected as to the height and distance to which ice floes travel up a beach from the pressure of grounding floes; notes should be made as to the effect of the ice masses on the rocks and beach material below, especially in regard to the production of striations on either of these, and the extent to which the latter may be incorporated in the lower part of the floe. Any contortions of the beach material should be sketched, with measurements of the dimensions of the contortions.

III. Structure of the Ice Barrier.

The origin of the Antarctic Ice Barrier, which extends Eastwards from Mts. Erebus and Terror, is still unsettled. As a contribution to the history of this ice, observations should be made as follows:

(1) Its intimate structure, including the size, form and arrangement of the ice-grains.

(2) The presence or absence of included layers of earth and stone; and, in the former case, their thickness and arrangement should be noted, their forms and the nature of the materials contained, their mode of weathering at the surface, the effect which they may produce on the movement of the ice, and their relation to shear planes; for it

has been suggested that an abundance of included material may greatly retard, possibly even arrest, the movement of the lower layers. Sketches or photographs of them should be taken.

(3) If any fine streaks are present, their direction, number and arrangement should be noted.

(4) Specimens should be collected of any included rock fragments or mud.

Such observations can be taken better on the face of the Barrier than on its surface; and the same rule is applicable to the study of all forms of ice. In crossing the upper surface of the Barrier, the most important point to observe is the arrangement and distribution of the crevasses.

It would be interesting to know the area of the Ice Barrier and the direction of its movement.

IV. Land Ice.

The Land Ice will probably be found to consist of inland ice sheets and of tributary valley glaciers.

In addition to a general topographical description of the forms and distribution of the ice, observations may be made on the following lines:

(1) *Glacier Terminations.*—These will probably be either vertical faces (Chinese Walls) or tapering snouts. The directions towards which they face should be noted, and several of the 'Chinese Walls' should be studied in full detail. Observations should be made of the structure and thickness of the successive layers; the amount of and nature of the material included in the different layers of the ice; the overhang, if any, of the top layer; the mode of advance of the glacier as a whole; the effect of the advancing glacier on obstacles in its path, such as the moulding and sculpturing of the rocks over which it passes; whether its action is erosive as well as abrasive, and how far such action is dependent on the magnitude of the ice stream, and on the slope, or changes in the slope, of the surface over which it is passing. In some cases a glacier appears to advance over a causeway of its own building; that is, by overriding its own terminal moraine (constructed in Greenland very largely of material transported in the lower part of the ice); in other cases, probably dependent very largely on the amount of the slope, it thrusts the material before it. The effect of subglacial streams and the arrangement of the ice beside their channels should also be studied.

(2) *Rate of Movement.*—Some measure of the snowfall from a given area may be obtained by estimating the discharge of ice by the glaciers therefrom. For this purpose the rates of flow of the glaciers must be measured.

It is at any rate essential that the average daily rate of flow should be determined for several typical 'Chinese Wall' glaciers, and for a typical 'snouted' glacier.

(3) *Nature of Glacier Movement.*—That glaciers flow like rivers was discovered long ago, but the cause and mode of this movement is still an open question. Many theories have been proposed in explanation of this, the most important of which are founded, directly or indirectly, on a study of the minute structure of glacier ice. All ice is composed of an aggregate of irregular crystalline grains, but the mode of aggregation of these grains differs materially in different kinds of ice. That of glaciers has been found to exhibit a structure more or less irregular, and sufficiently coarse to be visible to the naked eye, but further information is needed to determine its history and significance. The size, shape and optical arrangement of the glacier grains should therefore be carefully studied.

Information is especially wanted as to the crystallographic arrangement of the grains in the immediate neighbourhood of the shearing planes which are found in Arctic glaciers; especial note should be taken whether all the ice grains have their crystallographic axes parallel on both sides of such planes.

The study of the behaviour of the ice along these shearing planes is of great interest. If possible, any differences in the rates of movement on either side of a shearing plane should be measured. The changes that occur in the ice may be noted by taking successive photographs, at intervals of say a week, of one patch on a glacier face.

Further a block, including a shear plane, should be cut out of the glacier, and the power necessary to deform it, by pressure applied in different directions, should be determined.

(4) *The Growth of Glacier Grains.*—Attention should be directed to the growth of ice grains under strain. Notice whether one grain grows by the melting and absorption of surrounding grains, or whether cases occur in which all grains grow simultaneously by the introduction of water from elsewhere.

(5) *Internal Melting of Glacier Ice.*—The extent to which melting takes place in glaciers has been again made a matter of primary importance by von Drygalski's work in Greenland. His conclusions having been called in question, further data on this point are desired.

If glaciers move by the continual melting and re-freezing of the ice grains, then temperatures at which this can occur should be met with in glaciers. A platinum thermometer is the most suitable instrument to determine the temperature in the body of a glacier, but mercurial thermometers, buried at various depths, can also be used. A considerable series of observations should be undertaken to determine (1) the rate at which heat waves traverse the ice; (2) the depth affected by superficial changes of temperature; (3) the minimum temperature to be found in the lower part of a glacier.

(6) *Ablation.*—The extent to which the upper layers of a glacier are removed by melting and evaporation—known as ablation—must be systematically measured by driving graduated sticks into the ice.

In connection with ablation, it is advisable to determine the loss in weight of an exposed block of ice. In comparison with this experiment, similar measurements should be made as to the rate of solution of ice exposed in the sea at temperatures below the freezing-point of fresh water.

(7) *Thickness of the Antarctic Ice-Sheet.*—Estimates of the thickness of the Antarctic ice-sheet will be difficult to form. The only means of forming an approximate estimate may be by transverse sections across the country, showing the surface slope of the ice in reference to any rock-peaks that rise above it. The view that the ice will steadily increase in thickness to the South Pole, where it may amount to 20 miles, is apparently hypothetical, and not easy to reconcile with the known properties of ice.

(8) *Glacial Uplift.*—The fate of water produced by ablation should be traced if possible. The water, for instance, may percolate to low levels in the ice-mass and there be again frozen. In that case the layers of a glacier may be subject to a gradual uplift, due to the removal of the top layer and its transference by percolation and re-freezing to the bottom.

The uprise of the lower layers of a glacier has been assumed by some geologists to explain certain features of European glacial deposits, and it has been observed to occur on the margins of Arctic glaciers in Greenland and Spitzbergen.

To what extent material from the bed of the glacier is uplifted by such a movement should be carefully investigated. It is also possible that in some cases the ice-mass may be forced up hill by the pressure of that which is descending from a higher level, or in other words that a glacier may behave somewhat in the way of water at the foot of a steep slope. All proofs that any such thing has occurred should be

clearly recorded, and the relation between the height to which either the surface of the ice or material transported on or in it has been pushed up, and that from which the mass to which the thrust is due has descended, should be carefully observed.

(9) *Ground Moraine.*—Where glaciers can be observed resting directly on the ground, the lower layers will probably be found crowded with mud, pebbles and boulders. Note whether there is any layer of such material dragged forward by the movement of the ice above; and whether there is a gradual, imperceptible passage from frozen mud below the glacier into ice crowded with detritus, and from this again to ice with bands of detritus and thence to comparatively pure ice. Also how far such material can accumulate so as to form a cushion of any thickness between the lowest layer of ice, whether clean or dirty, and the live rock, and the circumstances under which such accumulation, if any, occurs.

(10) *Boulder Clay.*—Any signs of stratification in a boulder clay or till should be carefully noted, and any inter-bedding of this with sands or gravel. Such material, and especially the former, should be carefully searched for organic remains, and the mode in which these occur should be noted, whether broken or whole, or in positions of growth. Samples also of the clay should be secured, that they may be searched for ostracoda, foraminifera, etc. The included rock-fragments should be carefully studied, and the locality from which they have been derived should, if possible, be ascertained. Great attention should also be paid to their form, whether angular, sub-angular, or rounded; in other words, whether fragments obviously water-worn or the reverse are abundant or preponderant.

(11) Evidence as to whether the ice in Antarctic regions is now at its maximum extent, or whether it has anywhere retreated, should be carefully sought. Thus, wherever the ice does not actually come down to or beyond the sea margin, such indications of its former presence as rounded and striated rocks, perched blocks and moraines, should be recorded, and where any large mass of rock is visible, this should be carefully examined for inter-stratified boulder beds, in order to see whether there is evidence that the region has passed through more than one glacial age.

Two forms of deposited material, directly or indirectly associated with land ice, are still very imperfectly understood. One consists of the peculiar mounds of sand, gravel and rock fragments called Eskers, Åsar, or Kames. These sometimes bear a general resemblance to moraines, at others are more like rude and magnified copies of rather

dilapidated railway embankments. The coarser materials are usually more water-worn and the whole more distinctly stratified than in moraines, the stratification not seldom exhibiting in transverse sections an arched structure, roughly concordant with the exterior of the mound. These eskers may sometimes be traced for many miles, and commonly, though not invariably, follow the lowest part of a valley. The other, called Drumlins, are also mounds, but very different in shape. Their ground-plan is an oval, the breadth being about one-half or two-thirds of the length, which may vary from a few hundred feet to a mile, and the height from twenty-five to two hundred feet. They are smooth and regular in contour, having steep sides and a gently sloping rounded top. The material is a compact clay filled with foreign and finely striated stones, very imperfectly, if at all, stratified. In any limited area the longer axes of a group are generally parallel, and point in the same direction as the glacial striæ on neighbouring rocks. Supposing either Eskers or Drumlins to exist on ice-free portions of the Antarctic land, it will be important to observe whether they occur on tracts over which a glacier can be proved, by the usual indications, to have passed, together with anything which may throw light on their relations to it and on the mode in which they have been formed.

XIII.

INSTRUCTIONS FOR COLLECTING ROCKS AND MINERALS.

By L. Fletcher, M.A., F.R.S.

From the collector's point of view, Minerals differ in many respects from both Animals and Plants: the individuality being little pronounced, a specimen may be broken in two, and yet often be as satisfactory as before in its illustration of the characters of the material; the characters themselves are independent both of climate and seasons and of mere longitude and latitude; the material, after collection, is comparatively permanent, and is generally free from that liability to decay which is a special feature of organic matter.

Meteorites.—Of the mineral products of Nature some are interesting as having fallen from the sky (meteorites): most of these (meteoric stones) are of grey stony matter, which is completely covered with a thin black crust, and contains particles of metallic iron dispersed through it; the others consist of metal (meteoric iron), which, though containing on the average about 10 per cent. of alloyed nickel, has an aspect like that of the iron of commerce. As native iron is extremely rare, any natural product consisting either wholly or partially of metallic iron is of special interest and worthy of collection.

Atmospheric Dust.—The dust which settles on a snow-covered region, far away from manufacturing districts and from exposed land, is of great interest as possibly having had its origin outside our own Earth. A large amount of the snow spread out on a clean sheet should be allowed to melt and drain away; the mineral residue can then be collected by brushing with a feather.

Rocks.—In general, rock-specimens are of little value, except in connection with a complete survey and description of the region by one who has given special attention to the study of mineralogy and geology, and has himself collected the specimens: rock-specimens collected here and there, and without correlative information as to

the geological structure of the district, are rarely worth the tro and expense of transport. But any traveller in a comparati unknown region, like the Antarctic, even though it contains ne mines nor quarries, may be of service by collecting material repr tative of all exposed rocks met with during his journeys. material should be taken, not from the margin of the rock whicl been long exposed to the action of the weather and is more or altered, but from the inner part showing uniformity of character. break off such specimens, the traveller should provide himself w hammer of which head and shaft are reasonably proof against frac "Mineralogical hammers" are articles of commerce, and are of ous weights and sizes; the head is of well-tempered steel, one e it being flat and square with an edge about 1 inch long, the othe having the shape of a chisel, the chisel-edge, also about 1 inc length, being at right angles to the shaft: for most purpo hammer of two pounds weight is sufficient. Strong chisels, 4 inches long, are also occasionally useful. A small trimming-ham from ½ to ¼ pound in weight, is convenient for use in the redu of specimens to a proper shape and size. The size adopted fo specimen must depend largely on the sizes of the individual mi constituents of the rock, since the specimen is to illustrate average characters of the mass, and also on the convenience transport: a good average size, if the specimens are intende exhibition, is, length 4 inches, breadth 3 inches, thickness from ½ inch. As rock-material is very heavy, the reduction in size sh be made at the place itself; another piece of the rock can the immediately got, if by any mischance the specimen be spoiled i course of the trimming. Where a rock shows variations of char specimens should be selected in illustration thereof.

The interest of a rock-specimen lies very largely in the rela of the mass of which it is a part to the other rock-masses i district; unless information as to the locality of the mass to v the specimen belonged is preserved, the specimen itself gene becomes valueless; for this and other reasons water-worn pe are not worthy of transport. Hence it is important to speci precisely as possible the place from which each specimen has broken, and also to take precautions against the possibility subsequent confusion of the localities of the specimens. A gun label should be fastened on each specimen immediately after i been trimmed, and a number should be written thereon referri a corresponding entry in a note-book in which all the memo relative to the locality and the specimen are recorded: among

may be included the hour and the date when the specimen was got, as giving a rough indication of the relative positions of the different masses on the line of route. The specimen should then be wrapped in newspaper to prevent friction with others; and, as a measure of precaution against the loss of the note-book and also as a convenience, the locality should be specified on the inside edge of the wrapper. It is also convenient if the wrappers of specimens from each particular district are distinguished by some external mark.

The specimens may be stowed in manilla bags, which are then sewn sufficiently tightly to prevent the shaking about of the contents. Wooden boxes should be small and strong, for large boxes containing rock-specimens are almost unmanageable during transport. Paper or straw makes good packing material; but sawdust is useless, as the specimens accumulate at the bottom of the box with the sawdust above them.

Minerals.—The specimens which show the characters pertaining to mineral species and varieties in the most perfect way are found, not at the earth's surface, but in the course of the working of mines and quarries. Specimens of simple minerals collected in an unworked region like the Antarctic by a traveller having no special knowledge of mineralogy, are likely to be of little scientific interest, though precious stones, metals and ores will have an obvious economic value.

A mineral specimen comprising delicate crystals should be wrapped first of all in soft tissue-paper, next in cotton-wool, and lastly in newspaper; it may then be enclosed separately in a small box, which may be put with others in a larger one.

XIV.

ZOOLOGY:

ANTARCTIC CETACEA.

BY R. LYDEKKER, F.R.S.

THAT whales are abundant at certain times of the year in certain parts of the Southern ocean, and that they resort to the coasts of southern Patagonia, New Zealand, etc., during the breeding season, is a well-known fact. For instance, Mr. W. S. Bruce,* in his account of the animals met with during the voyage of the ss. *Balæna*, of Dundee, in 1892–93, speaks of the great number of large whales met with in the Antarctic. And Mr. H. J. Bull, in a letter to *The Times* newspaper of December 25, 1895, testifies to the number of "blue whales" encountered during the cruise of the steam whaler *Antarctic*. "The number of blue whales," he writes, "in the Antarctic must be very considerable. On our cruise we noticed them more or less frequently from the 64° to the 74° south lat., between the long. of 165° to 178° east." These "blue whales," it appears, were rorquals, or finners. But, to go back to earlier years, Sir James Ross recorded meeting with numbers of what he regarded as right whales, or "black whales," in high Southern latitudes.

This latter statement has given rise to the idea that the Antarctic Ocean, like the Arctic Ocean, is the habitat of a right whale which frequents the edge of the ice for a considerable portion of the year, and only proceeds northwards for the purpose of breeding. And it was, to a great extent, with the object of capturing these supposed South Polar right whales that the *Antarctic* was fitted out and despatched. Needless to say the venture ended in disappointment; for, although the southern right whale undoubtedly travels far south during its journeys to and from its breeding resorts on the coasts of New Zealand and elsewhere, it is most certainly not an endemic polar species, analogous in its habits and distribution to the Greenland right whale. It is, in fact, distinctly not an ice-whale; and the same apparently holds good with regard to the rorquals and all the

* 'Proc. Phys. Soc., Edinburgh,' vol. xii. pp. 350–354 (1894).

other large cetaceans of the Southern seas. Some, like the pigmy whale and the southern bottle-nose, are peculiar to the seas of the Southern Hemisphere, but none appear to be exclusively denizens of the circumpolar ocean. That is to say, not only is there no Antarctic representative of the Greenland right whale, but there is no cetacean in the southern seas corresponding either to the white whale (*Delphinapterus*), to the black fish (*Globiceps*), or to the narwhal of the North Polar ocean. Of course there is the possibility that such a creature may be discovered, but none is known to science at the present day.

Of many of the cetaceans that habitually frequent the Southern ocean the species is definitely known, but in other cases—notably among the rorquals—our information in this respect is most defective. Any observations as to the time when whales that can be specifically, or even generically, identified visit particular latitudes, and how far south they range, would be of the utmost value. If specimens are captured, and it is found impossible to bring home the entire skeleton, the best plan would be to preserve the skeleton of one of the flippers, one half of the lower jaw, and the two shell-like tympanic bones of the inner ear.

Of the larger cetaceans definitely known to range as far south in the Antarctic seas as lat. 50°, or thereabouts, the most important is the southern right whale (*Balæna australis*). It may be recognised by its black colour, short and deep build, enormous head, and the absence of a back fin. It has the usual long whalebone of the right whales, although the plates of this substance are much shorter, and therefore less valuable, than those of its Arctic relative. Whether this whale was ever abundant in the Southern seas, and, if so, whether its numbers have been seriously reduced by expeditions despatched from southern ports, are points upon which information is required. In the southern winter they are known to journey northwards to breed, but we have no knowledge how far south they habitually go at other seasons, nor their lines of route.

The other right whale of the Southern Hemisphere is the pigmy whale (*Neobalæna marginata*), a species peculiar to these seas, and only growing to a length of about twenty feet. It may be recognised by its white "bone." Originally described in the 'Zoology of the *Erebus* and *Terror*,' by Gray, from Western Australia, it was re-named by him on the evidence of specimens from New Zealand, and has been of late years identified by Dr. Moreno* on the Atlantic side of South America. Its only commercial value would apparently be for its oil, and of this there would be no great amount.

* 'An. Mus. La Plata; Seccion Zoologica,' iii. (1895).

As mentioned above, Mr. Bull records numbers of rorquals from the Antarctic, but there is practically no definite information as to the species to which these belong. It is true that the name *Balænoptera* (or *Physalus*) *australis* has been applied to one of the larger forms from the Southern Hemisphere, but no characters have been given by means of which it can certainly be distinguished from the northern species. A smaller form from New Zealand has been named *B. huttoni* by Gray, but its right to distinction from the northern pike-whale (*B. rostrata*) has yet to be demonstrated. The British Museum possesses the tympanic bones of a large rorqual from Magellan Strait, and a second from Cook Strait, New Zealand.

Humpback whales (*Megaptera*) are known to range into the Antarctic, and specimens from New Zealand have been described by Gray as *M. novæ-zelandiæ*, while the Cape form has received another name from the same writer. Sir W. H. Flower considered, however, that neither of these are separable from the northern *M. böops*. This view is provisionally followed by Dr. Moreno † when recording the occurrence of the genus in Argentine waters. How far south the humpback ranges is at present unknown, and accurate descriptions of the coloration of any examples seen would be valuable.

The sperm-whales of the South seas were regarded by Gray as distinct from the typical *Physeter macrocephalus*, and have received the names of *P. polycyphus* and *Catodon australis*, but there is no reason to believe in the existence of more than one southern form, or that this is really different from the northern animal. Information with regard to the southern limits of the range of the sperm-whale would be most valuable; also, whether there are any large old males now living which show the abrupt truncation of the muzzle exhibited in the illustrations to Beale's well-known 'Whaling Voyage,' and in other old pictures. Photographs of this whale when "breaching" would be of especial interest.

The lesser, or short-headed, sperm whale (*Cogia breviceps*), first described by Gray in the 'Zoology of the *Erebus* and *Terror*,' seems to be, in the main, a southern form, occurring in Australian and South African waters, although it, or a closely allied species, has also been taken at Madras. Very little is known as to the external characters of this species, and coloured sketches, photographs and measurements, would be most valuable. It is a light-coloured cetacean, growing to a length of about twenty feet, with no back fin, and a full series of teeth in the lower jaw but none in the upper. Whether it ranges into the Antarctic is not known.

† *Op. cit.*

The bottle-nosed whale of the Southern seas was described, in 1882, by Sir W. H. Flower as a distinct species, under the name of *Hyperöodon planifrons*, on the evidence of a battered skull from the Dampier Archipelago; and Dr. Moreno* has shown that this form is a perfectly valid species, met with on both sides of lower South America. Bottle-nosed whales, which must not be confounded with the dolphins of the same name, grow to thirty or forty feet in length, and are remarkable for the great elevation of the forehead of the old males above the beak. They are dark-coloured, and have a single pair of pointed teeth near the front of the lower jaw. Information is required as to how far south bottle-nosed whales occur.

The beaked whales of the sub-family *Ziphiinæ* appear to be more numerous in the seas of the Southern Hemisphere than elsewhere, but how far towards the South Pole they are in the habit of wandering is still unknown, although three species have been recorded as occuring on the coasts of Patagonia.† From twenty to twenty-five feet is the ordinary length of these whales, which are generally dark-coloured above and light beneath. As their name implies, they are distinctly beaked, and they carry a back fin. They have one (occasionally two) pair of large and generally compressed teeth, situated about the middle of the lower jaw; and these, in *Mesoplodon layardi* attain an enormous length, growing in a strap-like form right across the upper jaw, and only allowing the mouth to open to a very limited degree. *Ziphius cavirostris*, *Z. chatamensis*, *Mesoplodon australis*, and the aforesaid *M. layardi*, are the best known Southern types. A desideratum in collections is *Berardius arnuxii*, typically from Chatham Island, which is at present represented in the British Museum only by a single tooth. One of the features of the genus is the great basal extent of this tooth, which is much compressed. As none of these cetaceans are of a large size—that is to say, comparatively speaking—no great difficulty should be experienced in preparing and storing skeletons of any examples that might be taken. Photographs and sketches of these cetaceans, in the flesh, should also be taken if opportunities occur.

The remarks in the two preceding sentences apply with equal force in the case of the dolphins and porpoises found in the Southern oceans, of which our knowledge is still extremely imperfect. Any specimens, with authenticated localities, would be valuable.

* *Op cit.* † *Cf.* Moreno, *op. cit.*

XV.

ZOOLOGY:

SEALS.

By G. E. H. Barrett-Hamilton, B.A. F.Z.S.

(Copied from the British Museum Report on the voyage of the *Southern Cross*, by permission of the Director of the Natural History Museum).

When it is considered how frequently sealing and whaling vessels have visited the Antarctic and how heavy has been the toll levied upon the marine mammalia of those regions, it is astounding how little is really known of these animals. Leaving out of the question the Sea Elephant (*Macrorhinus*), whose valuable commercial properties made it the object of a pursuit so keen that it seems to have been well-nigh wiped out of existence, we find four species of true seals represented in collections from the Antarctic. These are the Crab-eating or White Seal (*Lobodon carcinophagus*), Weddell's Seal, or the False Sea Leopard (*Leptonychotes weddelli*), the Sea Leopard (*Ogmorhinus leptonyx*), and Ross' Seal (*Ommatophoca rossi*). All these are at home on the pack-ice of the extreme South Polar regions, probably at all portions of its area, a habitat for the occurrence in which either of the Sea Elephant or of any species of Eared Seal we have, I believe, no evidence. Three of them are not confined to the pack-ice, but have been found elsewhere. The single exception is Ross' Seal. No other species has ever been brought from the Antarctic, and it is highly unlikely, in spite of certain statements to the contrary, that any remarkably new form of mammalian life, at least among the Pinnipeds, remains there undiscovered.

Of these four species the earliest to attract the attention of zoologists, and perhaps the best known to science at the present day, is the Sea Leopard, a species which was first recognised as distinct by de Blainville in 1820. In 1822 appeared the first notice of Weddell's Seal in the shape of a short description by Professor Jameson in 'Weddell's Voyage to the South Pole,' to be followed by its correct description in binomial terms by Lesson in 1826.

Next in order comes the Crab-eating Seal, discovered by the French expedition in 1837–1840. This species formed the subject of two plates in Jacquinet's and Pucheran's 'Zoological Atlas,' published some time between 1842 and 1844. Lastly Ross' Seal was discovered by Sir James Clarke Ross during his voyage of 1839–1843, and described by J. E. Gray in his account of the 'Zoology of the Voyage of H.M.S. *Erebus* and *Terror*,' published in 1844. Sir James Ross' expedition obtained specimens of each of the four species, and accordingly Gray's work became and still remains the standard description of them all. It actually contains in fact the first written description of the Crab-eating and of Ross' Seal, and the first intelligent description of Weddell's Seal.

From 1844 until the nineties practically no specimens, except only those brought home by sealers, have reached our museums, and even the *Challenger's* share of the spoil, although fortunately described by Sir William Turner in 1888, reached only rather meagre proportions.

It is not surprising then, that, while we actually knew nothing of the appearance and habits of any of the four species, two of them (Weddell's and Ross' Seals) might until a year or two ago have claimed, and claimed justly, to be considered amongst the rarest and most obscurely known of all mammals. Of the latter species, in fact, only the two original specimens were known to exist. A third skin, the skull attached to which has disappeared, is preserved, as Professor D'Arcy W. Thompson has been good enough to inform me, in the town museum at Dundee.

Very welcome, then, were the specimens brought back by the *Belgica* in 1899. Although not numerous, they were excellently preserved and carefully labelled, and in all cases the sex of each specimen had been ascertained. I count it a distinct privilege to have been permitted to describe and study the first scientifically procured specimens of their kind which have reached this country. In this collection all four species were represented, and the four skulls of Weddell's, and two of Ross' Seal which formed a part of it, must be regarded as a special prize.

The *Southern Cross* collection, like that of the *Belgica*, contains specimens (both skins and skulls) of each species, the greatest rarities being four skins and skulls of Ross' Seal. Weddell's Seal is poorly represented by skulls, but numerously by skins; of the Sea Leopard there is one skin and skull, and about fifteen skins and skulls of *Lobodon*. It is most unfortunate that, owing to the unlucky death of Mr. Nicolai Hanson, the zoologist to the expedition, his private notes

have been lost. This and the fact that the metal labels which had been attached to the specimens have been in nearly all cases corroded through immersion in brine detracts greatly from the importance of what would otherwise have been a most valuable collection.

HABITS, LIFE-HISTORY, ETC.—It may be said with truthfulness that until the last decade of the nineteenth century we knew practically nothing of the habits of the Antarctic seals. At that date, with reviving interest in the exploration of the South Polar regions, several efforts were made to supplement our information on these subjects, so that at the present time our knowledge, although far from adequate, is no longer a complete blank. I have thought that, in the present scrappy state of our knowledge, it is better to give in detail the observations of the various observers than to attempt a summary which, at the best, would need almost immediate revision.

The Antarctic summer of 1892–93 found the Scottish whalers *Diana*, *Balæna* and *Active* in the neighbourhood of Joinville Island and Louis Philippe Land. Mr. W. S. Bruce, who accompanied the *Balæna* as naturalist, has given us a few notes on the seals which he observed. These, although I suspect that his identification may have been in some cases mistaken, are graphically written, and give us a fair picture in a general way of the mammalian life of the Antarctic.

Mr. Bruce found all four species on the pack-ice, where, "loving the sun, they lie on the pack all day digesting their meal of the previous night, which had consisted of fish or small crustaceans, or both. . . . All the seals were obtained from the pack-ice, in bluest and clearest water. . . . The present generation had never seen man, and at his approach they did not attempt to flee, but surveyed him open-mouthed and fearful, during which process they were laid low with club or bullet. Sometimes they are so lazy with sleep that I have seen a man dig them in the ribs with the muzzle of his gun, and, wondering what was disturbing their slumbers, they raised their head, only too quickly to fall pierced with a bullet. . . .

". . . In December all the seals were in bad condition, thinly blubbered and grievously scarred, and it is noteworthy that the females appeared to be as freely scarred as the males. During January their condition improved, and by February they were heavily blubbered and full of scars. The males were apparently as numerous as the females, but I made no definite statistics. . . . By February the embryo is well developed, gestation probably beginning in December. . . . Almost every female, towards the end of January

and February, is with young. In no individual did I find more than one embryo. . . ."

The seals showed great power of jumping out of the water. On one occasion some were found "on a tilted berg, and so high was the ledge above the level of the water," that Mr. Bruce relates, that the sealers only "clambered up with difficulty and secured their prey." He has seen the seals "rising eight or ten feet above the sea, and [they] cover distances of fully twenty feet in length."

The extraordinary scars and wounds observed on the seals, as described by Mr. Bruce, have been already noticed by previous naturalists, and attributed to various causes. One of the most fanciful theories ascribed them to the attacks of a large and unknown terrestrial carnivorous mammal corresponding to the Polar Bear of Arctic regions. No traces of any such mammal have been found by later expeditions.

These scars are also described by Mr. H. J. Bull, who gained his experiences of the seals in 1894–95 during a sealing and whaling trip to Victoria Land.* Mr. Bull states that "nearly one half of the seals captured" exhibited the peculiar scars or wounds. These wounds, which were in some cases "quite fresh—in fact bleeding—are not found about the necks and heads of the animals, but about their body, more particularly the lower parts." Their peculiarity consists in their great length—"up to twelve inches," and their frequently parallel arrangement at a distance of "about one inch apart." Their nature and appearance as described above, together with the fact that "the wounded seals were met with throughout the pack, consequently in many cases hundreds of miles away from the nearest land," are, thinks Mr. Bull, a death-blow to the theories which ascribe them either to the work of a "huge land mammal" or to the fighting of the males in the breeding season. Far more likely is it that they are caused by the attacks either of some shark, or, more probably still, by the Killer-whale, a cosmopolitan cetacean, with a well-known reputation for a partiality for seal-flesh. Mr. Bull's opinion is strengthened by the fact "the scars were rarely, if ever, found on the sea-leopards," "as if the size of this animal rather awed the mysterious enemy of his smaller cousins." Some further observations on this subject have been made by Mr. W. G. Burn Murdoch in the work quoted in footnote.†

* 'The Cruise of the *Antarctic* to the South Polar Regions.' London, 1896. See pp. 139 and 187 to 194.

† 'From Dundee to the Antarctic: an Artist's Notes and Sketches during the Dundee Antarctic Expedition, 1892–93. London, 1894.

My own experience of the Northern Fur Seal (*Callotaria ursina*), and its apparent apathy in the water when in close proximity to its enemy, the Killer, makes it seem highly probable that if the seals of the Antarctic be only half as foolish as the Fur Seals—a supposition which seems to be well-nigh proved by the ease with which they allow themselves to be killed by man—then many would easily fall victims to the Killers or sharks, who might scar many more than they eat, either in a mere spirit of wantonness, or, if well fed, through sheer half-heartedness in securing their prey. It is significant that Mr. Bull's experience of the pack was gained in December and January, exactly at the time when Mr. Bruce found the seals heavily scarred, but improving in condition. It seems probable that on the pack in January and February they are safe from their enemies, whoever they be. It may be that food is then so abundant that there is no need to leave the pack for the purpose of obtaining it, and so the seals escape exposure to the attacks of their enemies. It may be that those enemies are migratory, as the Killer is said to be, and have already betaken themselves to other regions. At all events the subject is well worthy of further attention.

Besides his account of the scars observed on the seals, Mr. Bull's most interesting statements are (for a naturalist) the fact that, while all four species were observed in the pack, they were evidently in no great numbers. The whole catch, in fact, reached only 180 skins.

Capt. C. A. Larsen, of the Norwegian whaler *Jason*, has given us a few notes * as the result of his visits to the regions east of Graham Land in 1892–93 and 1893–94. At some places seals (the species is not specified) were found in enormous numbers, especially in localities "where there were plenty of small fishes and shrimps." One hundred and twenty-five *Fiskerel*, killed on December 1st, 1893, are described as being "very big and fat." On December 11th, near Christensen Island, "The seals lay in places so closely packed that we had to make circles in order to advance. It was a delightful sight to see those masses of animals, most of which proved to be youngsters of the *Fiskerel*, which already had changed hair; they were beautifully fed, and looked like so many balls. Here and there an old animal was amidst the youngsters. The seals were not a bit afraid of us; on the contrary, they stretched their flippers towards us as we pelted them. . . . There must have been here abundant food for the seals, as the ice was everywhere strewn with fishes and fishbones. When I opened the stomachs of the seals I saw them filled

* See the *Geographical Journal*, vol. iii., January to June, 1894, pp. 239 and 336; also vol. iv., pp. 333 to 344.

with a fish which has a white flesh, and which we call at home *Kvitting* (Whiting), and also with sharp bones.

Like other explorers, Capt. Larsen sometimes found dead seals. "In one of the valleys," near Cape Seymour, Louis Philippe Land, "many dead seals were seen, one of which also was almost petrified, while others seemed to have come only recently here; and there were corpses in which the fat still contained some streaks of blood."

Monsieur Racovitza, the naturalist of the *Belgica*, has also published some highly interesting observations on the seals which he encountered in the pack-ice in the neighbourhood of Palmer Land in the same region. These will be found under each species. Of special novelty are the description of the appearance and strange and unexpected vocal powers of *Ommatophoca*. As regards food, it would seem that small crustaceans and other invertebrates are so abundant that the life of all, with the single exception, probably, of the Sea Leopard, consists, except in the breeding season, of a monotonous alternation of heavy gorging and long sleeps during the digestion of a meal which needs no trouble to procure.

Monsieur Racovitza has something to say about the body temperature, which, as in the case of the Penguins, he found remarkably low. In the case of the Seals it did not exceed 37°. So efficacious is the protection against the cold afforded by the thick layer of blubber which underlies the skin in these animals that the carcase of a seal killed twenty-four hours previously and exposed to a temperature of 20° was still warm interiorly.

Of his experience on the *Southern Cross* off Victoria Land Mr. Borchgrevink writes, that the seals "encountered in the pack on the southward voyage were, as they always have been found in the Antarctic regions, scarce. . . . As we proceeded southwards the number of seals basking together increased considerably, and in the vicinity of Coulman Island and Cape Constance, in Lady Newnes Bay, we saw as many as 300 together. These were Weddell's seals. . . . In the vicinity of Cape Adare seals were to be found nearly all the winter, either on the ice near their blow-holes or in the water at these holes, which they managed to keep open in Robertson Bay nearly all the winter. . . . The seals, like the penguins, provided us with fresh food."

It is obvious that we are still in sore need of careful and detailed studies of the life-history of each species, of their habits during the breeding season, and, above all, of the circumstances which admit the existence side by side of four species each distinct enough to form a separate genus, and whose very dentition differs in a highly

remarkable degree. Such marked diversity of teeth and skull cannot be meaningless, yet, except in the case of *Ogmorhinus*, no observer has as yet laid special stress upon any corresponding divergences of habits or life-history.

Owing to the unfortunate death of Mr. Hansen, and the loss of his zoological notes, the *Southern Cross* expedition has not had for one of its results any striking enrichment of our knowledge of the habits and life-history of the Antarctic *Phocidæ*. No MS. of any sort dealing with this subject has been placed in my hands, but Mr. Borchgrevink occasionally mentions seals in a paper read before the Royal Geographical Society. These, wherever they deal with a particular species, are alluded to under the heading of that species. The more important general notes tell us that seals were scarce in the pack, increasing in numbers, however, as the ship proceeded southwards. As to the moult of the seals Mr. Borchgrevink remarks (p. 382), "The moulting starts on the back, in a straight line from nose to tail."

As regards *migratory movements*, if any, on the part of the seals, we have practically no evidence of their existence. Mr. Borchgrevink's remarks certainly do not lend any support to the existence of any extensive migration. Any observations bearing on this subject would be of much value.

DENTITION.—The teeth of the *Phocidæ* are remarkable for the extreme variety which they display in the various genera. In most cases dental characters present the most distinct features of animals which are externally very similar. In the skin, as seen in museums, *Leptonychotes* and *Lobodon* are, but for their colour, difficult to separate; nothing could be more distinct than the forms of their respective teeth. It is evident that, whereas the needs of existence do not tend towards any very great variety of bodily shape, the food of the *Phocidæ*, or the method of securing it, may be so varied as to have induced the evolution of so many quite distinct types of dentition, the production of which postulates great plasticity of the teeth. The result is that the *Phocidæ* have already, by their teeth, shown themselves to be on the road to division into groups corresponding with some of those of the terrestrial mammalia. Thus, while *Ogmorhinus*, with its sinuous body and saw-like teeth, represents the most specialised form of Pinniped carnivore on a large scale, *Ommatophoca*, *Erignathus* and *Cystophora* represent more general feeders, while the smaller carnivora are respresented by *Phoca hispida* and *P. vitulina*—resemblances which seem to suggest all sorts of possibilities in dual evolu-

tion, possibilities of the rise of what now appear to be homogeneous orders of mammalia independently and in different regions, just as Dr. Kükenthal believes has been the case in regard to the whalebone and toothed whales.

In the whole zoology of the Antarctic *Phocidæ* nothing can be more remarkable than the divergencies in the shape and size of the cheek teeth. Side by side on the South Polar pack-ice occur four genera, *Lobodon*, *Ogmorhinus*, *Ommatophoca* and *Leptonychotes*. Living the same life, with the same sources of food around them, and moreover, armed with the same number of teeth, no two agree in any single respect in the form and pattern of the individual grinders. In *Ogmorhinus* there is found the most formidable, in *Ommatophoca* the most feeble dentition of the family; yet the feeble development of the teeth is in the latter supported by a lamdoid crest far exceeding that of *Lobodon* or *Leptonychotes*. Again, while *Lobodon* seems to find necessary for its existence a set of teeth surmounted by perhaps the most complicated arrangement of cusps found in any living mammal, *Leptonychotes* survives on the same ice-berg with the help of a simple, fairly strong dentition. Lastly, while there is, so far as is known, little individual variation in the three remaining genera, in *Ommatophoca* there occurs one of the most remarkable instances of individual variation in mammalian teeth known to science. Not only are the size and the number of the roots of each tooth variable, but the actual number of teeth in any particular specimen can never be foretold with certainty.

Few things can be more certain than that such a state of things as I have here described cannot be meaningless. Developments like these must in each case be connected with habits and food, which must surely differ in a manner corresponding to such remarkable differences of structure. This supposition is, I think, supported by the fact that, as already stated, there are to be found amongst the Antarctic *Phocidæ* resemblances of dentition to those of Northern seas. Thus it might be suspected that the resemblances between the teeth of *Ogmorhinus* and of *Phoca hispida* is not altogether without reference to similar uses.

With a view to approach the root of this matter I have examined with some care all the available accounts of the habits of the Antarctic *Phocidæ*. Meagre as these are there is enough in them to afford me some assistance, especially in the writings of Monsieur Racovitza. Thus the fact that *Ogmorhinus* is alone described as at least occasionally killing and eating penguins, and that it accepted as food the bodies of two of these birds thrown overboard from the *Belgica*, is

certainly in conformance with the formidable cutting teeth and massively developed cranial crests of this animal. The Sea Leopard may then be regarded as the true carnivore of the group, subsisting on fish (and, when they can be obtained, birds), a prey which need both catching and holding. For such a *rôle*, requiring both speed, strength and activity, besides teeth, its elongated head and body must be eminently suited. The three remaining genera are more puzzling. In their case no difference of food or habits had until recently been recorded. In spite of this I felt sure that the differences of dentition must be correlated with differences of habit, however inconspicuous. In *Lobodon* and *Leptonychotes* poorly developed cranial crests seem to indicate that no great violence of jaw action is needed, a character in the second case supported by the feeble dentition. In the first the teeth, although actually not of feeble size, are not of a shape which would lend itself to much use in gnawing and grinding, and the small extent to which they are actually worn down bears this out. It is then not easy to imagine what can be the use of teeth so unique in zoology. Possibly their formation may be explained by some words of Monsieur Racovitza. This naturalist's account of the feeding of *Lobodon* is as follows:—"Les *Euphausia* forment sa nourriture habituelle: il nage la bouche ouverte dans les bancs de ces crustacés, à la façon des baleines, et en consomme de grandes quantités." On reading these words I was at once struck by the idea that the teeth of *Lobodon* might possibly serve the animal as a sieve whereby to rid its mouth of the water taken in with the *Euphausia*, somewhat after the manner of baleen in the *Balænidæ*. For this purpose the teeth seem to be exactly suited. They do not fit closely, but alternate with those of the opposite jaw, so that the cusps form a perfect sieve. I believe then that the use of these extraordinary teeth is as I have suggested, and I would direct the attention of zoologists who visit the Antarctic in the future to what appears to be a point of great interest in the history of the animal, and is, I believe, a hitherto unparalleled function for the teeth of a mammal. Even, however, if my supposition prove to be incorrect, attention should be directed to the study of *Lobodon*, with a view to throw light on the use of its teeth. At all events, if extensively used for mastication they would speedily show the effects of wear and tear in a far more conspicuous manner than they actually do.

On the Antarctic pack-ice the food of *Leptonychotes*, like that of *Lobodon*, is said to consist of *Euphausia*. It teeth are highly different. I suggest that the form of the simple but not very strong teeth of this species is due to the fact that it is not confined to the pack-ice,

and in other regions its food supply is derived from creatures which need some holding, yet which are not so strong or active as those which serve to nourish *Ogmorhinus*. The external shape of *Leptonychotes* is that of an animal fitted for rapid motion in the water, so that it is natural to suppose that fish may form no small portion of its diet.

Lastly, we have *Ommatophoca*, with its very feeble and variable dentition, yet comparatively strong lambdoid crest. It is evident that the exact number of its teeth is not of importance to this animal. Even their size is sufficiently variable to admit the thought that the whole dentition is little used. It seems to me highly probable that *Ommatophoca* is in the process of losing its teeth. Its food is soft, consisting, according to Monsieur Racovitza, of large cephalopods. Such crushing of these as may be necessary would be performed as well by the flat jaws as by cusped teeth like those of the *Phocidæ*. Consequently the teeth are in a state of degeneration. But inasmuch as the large size of the cephalopods entails some munching, since they could hardly be swallowed whole, as might be the *Euphausia*, the muscles which move the jaws are necessarily stronger than in *Lobodon* or *Leptonychotes*, as shown by the fairly strongly developed lamdoid crest. This supposition agrees very well with that which I have already brought forward in the case of *Lobodon*. In the case of *Lobodon* the teeth are highly developed, not for grinding purposes, but for use as a sieve. In *Ommatophoca*, not being available as a sieve, they are useless. They thus fall outside the influence of Natural Selection, except in so far as their reduction may be of use to the species. Variation and enfeeblement results, a process which, if for the advantage of the animal, will no doubt be carried to its full extent. My supposition is supported by the external appearance of the animal as graphically described, I think for the first time, by Monsieur Racovitza. It is, he writes, "Le plus phoque des phoques, car chez lui toute forme de quadrupède a disparu. Son corps n'est plus qu'un sac fusiforme pourvu de membres très réduits," from which I gather that Ross' Seal does not possess the natural appearance which belongs to an agile carnivore such as *Ogmorhinus*.*

Leptonychotes Weddelli.

External Appearance.—This species seems to be recognisable rather by its negative than its positive characters. Although spotted, it is not so distinctly or abundantly so as the True Sea Leopard, so that

* See also Mr. Borchgrevink's description of his supposed new species of Seal under *Ommatophoca*, p. 223.

it comes in this respect intermediate between that species and Ross' Seal. Moseley described the specimen which he killed at Kerguelen Island as "very like the common British seal in appearance. It is spotted yellowish-white and dark grey on the back, the tender surface being of a general yellowish colour." Monsieur Racovitza characterises it as possessing "à pélage gris-fer moucheté de taches rondes de couleur jaune."

In *build* this seal is, judging by the photographs of Dr. Cook and Monsieur Racovitza, more slender than *Lobodon*. Monsieur Racovitza states that it is larger than the latter species. In that case the head should be proportionately smaller. It is relatively longer, more slender, and lacks the bluntness of *Lobodon*.

Distinguishing Characteristics.—Both the skull and skeleton of Weddell's Sea Leopard have been described in detail by Sir William Turner, at pages 20 to 28 of his report on the seals collected by the *Challenger* expedition. The skull has neither great size nor remarkable teeth to mark it off at a glance from the remaining seals of the Antarctic seas. Yet *Lobodon*, which is of very similar size, is the only form with which it could possibly be confused. Even here, however, there are several obvious points of difference, and *Leptonychotes* (apart from its simple teeth) may be at once distinguished by the proportionately greater breadth of its brain-case and the high narrow anterior portion of the skull, as well as by the shorter palate. The under jaws of the two animals are also characteristic, that of *Lobodon* being far deeper, stronger and more massive than that of *Leptonychotes*.

OGMORHINUS.

External Appearance.—The true Sea Leopard justly derives its name, since it bears more spots upon its body than any other species. In the single specimen brought home by the *Southern Cross* the spots extend all over the body, and Monsieur Racovitza says that the colour of the coat is "gris foncé, moucheté de taches jaunes."

The animal is, however, readily distinguishable by the great size of its elongated body. The longest measured by Mr. Bruce attained to a length of over thirteen feet, and the species gained the name of "serpent" from the sailors.

As regards the sexes, Mr. Bruce makes the interesting and unexpected statement that "Dr. Donald also noted that the females of the larger species were larger than the males"—a statement to which I would draw the attention of future explorers as well worthy of confirmation.

Distinguishing Characteristics.—The skull of the true Sea Leopard needs no description. It is well known, and has been described by Owen in the Catalogue of the Osteological Museum of the Royal College of Surgeons of London (see Nos. 3938 to 3941). It is at once distinguishable by two characters from the skull of any other living seal. These characters are—(1) the great length of the large skull, and (2) the powerful teeth, which are recognisable at all ages by their large proportions and the peculiar arrangement of the cusps. Of these there are three, placed one after the other in a line running parallel to the long axis of the jaw. The apices of the two smaller and outer are usually recurved towards the larger central cusp, which itself bears a recurved apex. In addition, it should be noticed that in no seal of the Antarctic are the lamdoid and sagittal crest so prominently developed as in this species.

LOBODON.

External Appearance.—Externally the Crab-eating Séal would appear to be the most conspicuous Antarctic species, as the names applied to it by the various explorers indicate. Thus, Mr. Bruce calls it "the Creamy White Seal," Mr. Borchgrevink styles it "the characteristic white seal of the Antarctic," and Mr. Bull writes of it as "the whitish-yellow or light grey seal which goes under the name of the white Antarctic seal, though it is never found of such whiteness that it cannot readily be distinguished on the ice-floes" (Op. cit. p. 139). Yet, except that we may be certain that it is at all ages of far lighter coloration than any of the other three species, we are as yet in some doubt as to its exact hues and their arrangement—doubt which can only be dispelled when a detailed description of the animal taken from specimens still in the flesh by a competent naturalist is forthcoming. Meanwhile it may be well to compare the various descriptions which have reached us. The original was as follows:—"Pélage brun olive, parsemé ça et là, en dessus, aussi bien qu'en dessous, de grandes plaques de couleur jaunâtre," a description borne out by the plate (No. 10), in which, however, the animal is represented as having the nose white. Mr. Bruce, on the other hand, writes of "a darker dorsal stripe," contrasted with the "creamy white" general body colour. The skins of all ages collected by the *Belgica* are nearly white, with only indistinct traces of mottling. In life they were, to once more quote Monsieur Racovitza, "d'un blanc pelucheux à reflet verdâtre." Lastly, the skins brought home by the *Southern Cross* show, as far as I could ascertain by an examination of them while

in salt, a considerable indication of indistinct spots or mottling, a character which is quite borne out by the specimens in the British Museum. Immature skins amongst these exhibit a considerable amount of mottling, and I strongly suspect that the Crab-eating Seal is one of those species the young of which shows traces of spots which are gradually lost as the animal grows older.

Dr. Cook's photographs seem to show us in *Lobodon* an animal somewhat intermediate in its proportions between *Leptonychotes* and *Ommatophoca*. Both head and body are thicker and blunter than in the former, but not so thick and blunt as in the latter form. The long flat anterior portion of the skull has a distinct effect on the physiognomy.

Distinguishing Characteristics.—The skull of this species is well known, so that a detailed description is uncalled for. Although not possessing the enormous dimensions of that of *Ogmorhinus*, it may be at once distinguished at all ages from that of any other species by the peculiar cheek-teeth. These are both large and remarkable for the complicated arrangement of cusps in which they terminate superiorly. As in *Ogmorhinus*, there is a principal central cusp, but this is supported, not by two others, one anteriorly, the other posteriorly, but by one quite small cusp anteriorly, and by from one to three posteriorly. The central cusp is far larger than the remainder, and its apex is usually bulbous; all have a tendency to point backwards. In addition to these dental characters, the skull of this species differs from the somewhat similarly sized *Leptonychotes* in its longer palate, and longer, broader, anterior portion, as well as in the shape of the lower jaw. This is in *Lobodon* far deeper, stronger, and more massively built than in *Leptonychotes*.

Ommatophoca.

Distribution.—Although probably poorer in numbers than the other three species, Ross' Seal is thus shown to have a fairly wide distribution, having been found (excluding Ross' own specimens, the locality for which is uncertain), so far as we know, in all cases on the pack-ice in the neighbourhood of Joinville Island and Louis Philippe Land (Bruce), west of Alexander Land (*Belgica*), and in the neighbourhood of Victoria Land (*Southern Cross*).

Habits.—Of the habits of Ross' Seal practically nothing was known until the publication of Monsieur Racovitza's interesting notes. As has been already stated, that naturalist found it, like Weddell's, the White Seal and the Sea Leopard, an inhabitant of the pack-ice, where it feeds exclusively on large cephalopods.

The most novel observation, however, is that which has regard to its voice, which is said to be very curious. The sounds which it emits are very varied. "Son larynx fortement gonflé constitue une caisse de résonnance, et le voile du palais très développé, distendu par de l'air, constitue à l'animal une sorte de cornemuse. On entend d'abord, chez la bête irritée, une sorte de roucoulement de tourterelle enrouée, auquel succède le gloussement d'une poule affolée de terreur, et la finale c'est un reniflement sans harmonie produit par l'air violemment expulsé par les naries."

External Appearance.—As in the case of the other species, the exact details of the *coloration* of *Ommatophoca* are still very imperfectly known. Gray's plate tells us very little. In his written description of the type-specimen he stated that the colour was "greenish-yellow, with close oblique yellow stripes on the side, pale beneath." The present coloration of the skin I should describe as being, as nearly as possible, olive above, shading gradually into tawny olive beneath, with regions of lighter yellowish shades on the breast and neck. There is no very distinct line of demarcation between the colours of the upper and under surfaces; neither are there many spots. The "stripes" described by Gray are, however, present at about the place where a line of demarcation might be expected to occur. On the flanks they occur as streaks of the colour of the under surface, having a breadth of about a quarter of an inch, which, running obliquely forwards, invade the colour of the upper surface. Occasionally, in places where the streaks are interrupted, a spot or two is formed. Otherwise the creature is spotless.

Mr. Bruce, in his very brief allusion to the coloration of this species, makes no mention of these streaks, but merely compares it with the Crab-eating Seal, adding, that its coat is "somewhat sleeker, of a beautiful pale mottled-grey colour, darker on the back and lighter on the belly, and varying in intensity in different individuals." The streaks are so well represented in the reproductions of Dr. Cook's photographs, published both in his own book and in Monsieur Racovitza's paper, that I cannot help regarding them as highly characteristic of the species. Mr. Bruce compares *Ommatophoca* with *Lobodon*, which, he states, that "in form and size" it is "very like." This remark about an animal which has been described by Monsieur Racovitza in such vivid language as so highly distinct from all the other species makes me suspect that Mr. Bruce may have been mistaken in his identification of Ross' Seal.

Unfortunately no skins of *Ommatophoca* were entrusted to me for examination by Monsieur Racovitza. The four skins secured

by Mr. Hanson are still in salt, and not in a condition suitable for description.

From the description of Monsieur Racovitza, *Ommatophoca* would appear to be of very remarkable *form*. It is, he says, "le plus phoque des phoques, car chez lui toute forme de quadrupède a disparu. Son corps n'est plus qu'un sac fusiforme pourvu de membres très réduites"—a description completely borne out by Dr. Cook's photographs, as well as by Mr. Borchgrevink's note (Op. and loc. cit.), that the body of the first specimen of this supposed new species "was not unlike that of the ordinary seal, but the neck was of more than ordinary thickness, and under the chin it extended to a great round muscular purse. The head was short and broad, the eyes large and protruding, and the mouth short. The eyes were somewhat slanting. It had six front teeth in the upper jaw, two in the under jaw, but no back teeth." The four skins brought home by the *Belgica* are those of an animal distinctly smaller than the other three species. Their total length, measured from the tip of the nose to that of the tail, reaches only from four feet four inches to four feet ten inches. The thick and hairy tail presents no characteristic features, having a length of about four inches. The flippers, as in the other species, are completely covered with hair. They are distinctly smaller than those of *Lobodon* or *Leptonychotes*. The fore-flippers carry five, the hind two to five (in the latter case rudimentary) claws. The greatest lengths are, for the fore-flippers nine to twelve inches, for the hind ten to twelve inches. It is due to those who have worked only at the type skin to say that, like them, in examining it, I have completely failed to find any traces of claws on the hind-flippers.

Distinguishing Characteristics.—The skull of Ross' Seal cannot possibly be confounded with that of any other living Pinniped. Its nearest resemblances lie with *Cystophora cristata*, Erxleben, of Arctic waters. In general size it about equals that of *Leptonychotes*, and is slightly smaller than that of *Lobodon*. Here the resemblance ceases. The feeble dentition, broad interzygomatic and short naso-palatal regions, together with the vertical inclination of the nares, at once mark *its distinctness*.

Sex.—The sex of Ross' specimens is unknown. Both those collected by the *Belgica* were females. Since one of the known females is the largest skull of the four, and there are no apparent differences in the size of the teeth, I see no way of telling the sex of the two unknown skulls. Neither can the one unknown female amongst the skulls brought home by the *Southern Cross* be certainly indicated—unless, indeed, it be No. 1, which, although distinctly adult, is the

smallest skull of the eight known. All things considered, it is evident that there can be no striking differences between the sexes of this seal, and it is as likely as not that differences of size represent age and not sex.

Dentition.—Undoubtedly a great deal of the interest aroused by *Ommatophoca* centres in its dentition, owing to the remarkable variations shown by the different skulls as yet examined. On this account it is hoped that as large a number of skulls as possible will be obtained by the present Expedition, and that especial care will be given to their sexing. No number of sexed skulls, of whatever age, can be too great to be of value, for the present is a particularly important animal to students of variation, and for the proper study of its eccentricities in dentition very large series are required.

XVI.

ZOOLOGY:

BIRDS.

BY HOWARD SAUNDERS, F.L.S. F.Z.S. F.R.G.S.

IN giving a short account of the Birds of the South Polar regions, it has seemed advisable to begin by according prominence to those species which are known to occur within the Antarctic Circle, and thence enlarge the radius northwards to lat. 60°, or even a little beyond, so as to include many other inhabitants of the Southern seas. It is true that, by the adoption of this plan, scientific arrangement is subordinated temporarily to convenience of treatment, but this irregularity can be rectified by giving a systematic list in an Appendix, with cross-references to the earlier portion.*

The PENGUINS seem to be the most characteristic birds of the Antarctic regions, and, as regards dimensions, the most remarkable of these is the gigantic EMPEROR PENGUIN (*Aptenodytes forsteri*), the weight of which ranges from 57 lbs. to 78 lbs. This, and the Adélie Land Penguin (to be mentioned hereafter), are the only members of the family which inhabit the seas within the Antarctic circle during that part of the year which is called summer; the Emperor Penguin, therefore, ranges much further to the Southward than does its handsomer, but smaller congener, the King Penguin (*Aptenodytes patagonica*). Examples of the Emperor Penguin were taken on the expedition of the *Erebus* and *Terror* as far south as lat. 78°, off Victoria Land, where the *Southern Cross* expedition has recently obtained specimens; and Wilkes secured a single individual at Peacock Bay, in 65° 55′ S. and 151° 18′ E., which is not very far from Adélie Land, where, however, Dumont d'Urville does not seem to have observed the species. From the area known as Enderby's Quadrant it has not yet been recorded. Ross, on his third attempt at the South Polar regions, found the Emperor Penguin in considerable num-

* The names of the species found within the Antarctic Circle are printed in small capitals.

bers in the vicinity of Louis Philippe Land and Joinville Island, about 63° 36′ S. and 54° W., at the end of December 1842. On January 2nd, 1843, an example weighing 68 lbs. was obtained at Cockburn Island, and from a remark made by Dr. McCormick, Surgeon to the *Erebus*, it might be inferred that there was a 'rookery' of this species, as well as the undoubted one of the smaller and very plentiful Adélie Land Penguin, but Ross would not allow McCormick to land and explore. In 1892–3 the Dundee whalers, *Balæna* and *Active*, as well as Capt. Larsen, of the Norwegian s.s. *Jason*, obtained specimens in that area, and the Belgian expedition in the *Belgica* brought back three examples from about 70° S. and between 82° and 97° W., in the ice pack.

So far, therefore, as present knowledge goes, the Emperor Penguin ranges longitudinally from 151° E. in Victoria Quadrant, through Ross Quadrant, and to about 50° W. in Weddell Quadrant. In the stomachs of examples obtained were the beaks of large cuttle-fish, schizopods, crustaceans, fish-bones and pebbles. Nothing definite is known of the breeding-place of the Emperor Penguin, but in the collection of Mr. J. H. Walter, of Drayton House, Norwich, there is an egg which is decidedly larger than the well-known egg of the King Penguin; it was purchased by his father about half-a-century ago, and has no further pedigree than 'Antarctic regions,' and its appearance. Great pains have been taken to find any clue to a breeding-place, but unsuccessfully.

The King Penguin (*A. patagonica*) has not been recorded within the Antarctic circle, but mention of it in this place seems expedient, because it is the only other member of the genus *Aptenodytes*, and has even been confused by some ornithologists with its larger relative noticed above. Weddell found the King Penguin breeding on South Georgia Island, and he describes the beauty of its plumage just after the moult, as well as the way in which the bird carries its single egg in a pouch situated between its legs and tail; while Pagenstecker and Steinen, in their accounts of the German Expedition in 1884–5, have given later and fuller details with illustrations of the young in down. The King Penguin visits Tierra del Fuego and the south-eastern portions of the Straits of Magellan, as well as the Falkland Islands, though it is no longer known to breed there; while eastward, Moseley found it incubating on Marion Island, it is plentiful in the Crozets, and it undoubtedly breeds on Kerguelen and Heard Islands. Moseley's description of its habits on Marion Island, and Hazard's photograph* taken on Kerguelen, fully confirm Weddell's statement as to the manner in which the egg is carried. Still further east, the King

* *Auk*, 1894, p. 280, pl. viii.

Penguin has been recorded from the Stewart and Snares Islands, off New Zealand, and as far south as the Macquarie group, so that its range is far wider than that of its congener.

These two species may be easily distinguished from any other Penguins by their size, as well as by the slender shape of their bills, which are decurved at the tip. In both species the general colour of the upper parts is bluish grey, but in the Emperor a yellow semi-circular patch on each side of the head shades into white on the throat, whereas in the King orange-yellow bands on the sides of the neck join the orange on the throat to large yellow patches on each side of the nape.

By far the most abundant species within the Antarctic circle is the smaller blunt-billed ADÉLIE LAND PENGUIN (*Pygoscelis adeliæ*), named after the place of its discovery. This is the black-headed species found in immense 'rookeries' on Victoria Land and Adélie Land, as well as in the area round Louis Philippe and Graham Lands, and at the South Shetland Islands. Near Cape Adare the first young were hatched on the 9th December and the latest in January, while by the 2nd February, when the *Southern Cross* left, most of the young had emerged from the downy stage. The naturalists who accompanied the Dundee whalers in 1892–3 speak of this as by far the most abundant species near Graham Land. Its range does not appear to extend far to the north of the Antarctic circle, and it has not been recorded from the Falklands, South Georgia Island, or further eastward, to the north of lat. 60° S., at any time of the year. Northward of lat. 63° S. its place seems to be taken by a slightly smaller Penguin with a white band across the crown, the 'Gentoo' of the Falklands, and the 'Johnny' of sealers (*Pygoscelis papua*), which, like the King Penguin, extends its range far eastward, being found at Marion Island, where Moseley described it, and in numbers on Kerguelen and Heard Islands; also at the Macquarie group, in lat. 55°, to the south of New Zealand. A third member of this genus, the Ringed or Bridled Penguin (*P. antarctica*), seems to be restricted to the seas between Louis Philippe Land, Graham Land, the Falklands and South Georgia, while it is not known to be numerous anywhere.

None of the Crested Penguins (*Catarrhactes*) are known to breed in the South American area to the southward of the Falklands and South Georgia. In these the 'Gorfoo,' or 'Rock-hopper' (*C. chrysocome*), is found: a bird which has a very wide range, passing by the Tristan da Cunha group to the Cape Seas, the Marion, Crozet, Kerguelen and St. Paul Islands, South Australia, and the New Zealand waters as

far as Campbell Island, in 52° 33′ S.; while, according to Dr. Meyer, it has once wandered to Java. Another, the 'Macaroni Penguin' (*C. chrysolophus*), comes within the limit of mention, inasmuch as it breeds on South Georgia, where it begins to lay in the last days of October (Steinen), which is very early for any species of Penguin; it also propagates in the Falklands, and eastward on the Prince Edward and Marion group, Kerguelen and Heard Islands. A third and closely related species of this genus is *C. schlegeli*, confined to the New Zealand seas, as far south as the Macquarie Islands. *Megadyptes antipodum*, another crested species, also reaches as far as Campbell Island. The small Penguins of the genus *Eudyptula*, of Australian and New Zealand waters, are far north of my limit. Of the genus *Spheniscus*, which is restricted to the seas of South Africa and South America, only the 'Jackass Penguin' (*S. magellanicus*) deserves mention, because it breeds on South Georgia and the Falklands. The distinctive characters of these species on the edge of the limit are given in the Appendix.

Passing to the widely distributed family of the Petrels (*Tubinares*), we find WILSON'S STORM PETREL (*Oceanites oceanicus*) among the few species which occur within the Antarctic circle. This bird is not much larger than our familiar 'Mother Carey's Chicken,' from which, as from any other of the small blackish Petrels, it can be distinguished by its unusually long legs, and the bright yellow colour of the webs between the toes. It was observed by Dr. McCormick hovering, like a swallow or martin, over the mast-heads of the *Erebus* when in the pack; and, on the third attempt to go Southwards, examples (now in the British Museum) were obtained off Louis Philippe Land, in January 1843. These birds were evidently incubating at no great distance, as their breasts were bare of feathers. Surgeon Webster, of H.M.S. *Chanticleer*, refers to the abundance of this species at Deception Island, one of the South Shetlands; and I venture the surmise that this may be the small Petrel which the German expedition found breeding at the end of December 1882, on South Georgia, and which is called *O. melanogaster* by Steinen. The *Belgica* obtained specimens in Gerlache Strait in January 1898, as well as in the pack at about 70° S. and 87° W., in January 1899. The *Challenger* Expedition secured several off the ice-barrier in February 1874, and examples were obtained on the *Southern Cross* expedition between 63°–66° S. and 161°–166° E. The first breeding-place definitely made known was, however, in Kerguelen Island, where the bird was discovered by the Rev. A. E. Eaton, the naturalist to the Transit of Venus expedition, in 1874–5. He found the single egg belonging to

each pair of birds, laid in January or February, in some crevice or hole among shattered rocks or large boulders; the egg, as usual with the Petrels, being of a dull white colour, with minute purplish-red spots tending to form a zone at the broader end: measurements, 1·3 by ·9 in. Subsequently, Mr. R. Hall has contributed some interesting details on the breeding of this, as well as other species, on Kerguelen.* Both sexes, he says, take turns at incubation, and about 8 p.m. the 'night-shift' comes in from the sea to go on duty, when the relief is marked by loud croakings; and few birds are to be seen over the land in the day-time. After the breeding-season Wilson's Petrel wanders widely; and, owing to the fact that it has been often observed on the coasts of Western Europe, including the British Islands, as well as on those of America up to Labrador, some ornithologists have assumed that it bred on the islands of the North Atlantic. Of this there is not the slightest proof; on the contrary, some of the birds obtained between the spring and autumn of our Northern Hemisphere are in moult.

Specimens of all the small Petrels are much wanted, and no opportunity of obtaining them should be wasted. If the vessel should be going slowly through the water, long threads trailing from the taffrail and slightly weighted at the end by a bit of sennit or soda-water bottle-wire, are very successful in causing an 'entanglement,' and when the birds have been identified and the latitude and longitude recorded, they can be liberated, if not required. It is only in this manner that any definite knowledge can be obtained of the areas visited by these wandering species.

Passing to the large family which comprises the stouter Petrels, known as the Puffinidæ, among the species especially characteristic of the Antarctic seas is the snow-white ICE PETREL, *Pagodroma nivea*, with satin-like plumage, jet-black eyes and bill, and graceful flight. This bird has been obtained as far north as the Falkland Islands, but it does not occur in any numbers until lat. 60° S. is passed, whence it can be traced as far southward as man has penetrated. Every expedition has noticed it; Ross found it laying its bluish-white egg, measuring 2·2 by 1·6 in., among the crevices of the cliffs at Cockburn Island; Surgeon Webster, of H.M.S. *Chanticleer*, met with the bird from January to March on Deception Island, South Shetlands; and the German expedition found it nesting at the end of December on South Georgia. From the Enderby Quadrant it has not yet been recorded.

Another species is the ANTARCTIC PETREL (*Thalassæca antarctica*), which was found by the *Erebus* and *Terror* expedition as far as

* 'Ibis,' 1900, p. 19.

77° 49′ S., in long. 181° 10′ E. It seems to occur along the ice-barrier, but I cannot find any definite account of its breeding-places. This species, which seems to be the 'aglet,' or 'eaglet,' of Weddell and early explorers, has the upper surface brown, and has 12 tail feathers; whereas its near ally, the SILVER-GREY PETREL (*T. glacialoides*), has 14 tail-feathers, and has consequently been placed by some authorities in another genus, *Priocella*. This latter species has a pale-grey upper surface and other distinctive characters, described in the Appendix. It reaches the ice-barrier, and a specimen was obtained by the *Belgica* just before her escape from the pack-ice, on 14th March 1899, in lat. 70° 40′ S. and long. 102° W.; while the *Challenger* brought back one example, taken on the edge of the pack, in about 66° S., on 14th February 1874. The range of this species extends along the Pacific coast of America, occasionally as far north as Washington Territory, and also to the Cape seas; while Kerguelen Island seems to be a breeding-place, although I am not aware of any authenticated eggs.

The well-known CAPE PETREL, or 'Cape Pigeon' (*Daption capensis*) is another of the medium-sized species which has hitherto succeeded in concealing its egg from the gaze of naturalists, although the bird has been found in burrows with its young on Kerguelen, and there can be no doubt that it breeds on South Georgia, as well as other suitable localities in the Antarctic regions. It occurs throughout the Southern seas, and has even been obtained on one occasion off Ceylon. At long intervals individuals have been taken in the North Atlantic, from the United States to the British Islands; but among the numerous birds captured at sea many are known to have been carried hundreds of miles before their eventual liberation, and this may account for occurrences so far beyond the usual limits.

No true Albatros has been obtained within the Antarctic circle, and very few species reach 60° S.; in fact Moseley remarks that the last White Albatros (*Diomedea exulans*) left when the *Challenger* was still 200 miles to the north of the pack.* The Sooty Albatros (*Phœbetria fuliginosa*) was, however, obtained by the *Challenger* on 10th February 1874, at the edge of the pack-ice.† But the GIANT

* It is true that in an abstract of Balleny's voyage (Journ. R.G.S. 1839, p. 517) the explorer is quoted as remarking upon 'one Albatros' in lat. 61° 30′ S., 'the first since leaving Campbell Island,' but this may easily have been a whitish Giant Petrel (p. 231).

† It was the shooting of an Albatros of *this* species, as narrated in Shelvocke's 'Voyage Round the World,' pp. 72–73 (1726), that supplied Coleridge with the idea elaborated in the 'Ancient Mariner.' Shelvocke says that after his vessel, the *Speedwell*, had passed the Straits of Le Maire and had reached 61° 30′ S., 'we had not had the sight of one sea-bird, except a disconsolate black *Albitross*, who accompanied us for

PETREL (*Ossifraga gigantea*), which approaches the larger species of Albatros in size, was observed by Dr. McCormick soaring over Possession Island, Victoria Land, and the *Belgica* found it a constant attendant in the ice-pack. The 'Nelly,' as sealers call it, is, in fact, the vulture of the sea, visiting every spot where carcases and refuse of seals and penguins, or any other means of subsistence, can be found. Its breeding and habits on Marion and Kerguelen Islands have been described by Moseley and others, and the bird probably nests on Heard Island; Webster found it on Deception Island, South Shetlands, from January to March; and, as regards South Georgia, where the eggs are laid in the beginning of November, the practical Weddell remarks that these are inferior in taste to those of other species. The beak of this voracious bird is very powerful, and assertions have often been made by sailors that it will attack a drowning man and accelerate his death. Dr. McCormick states that when, after leaving Kerguelen, the bo'sun of the *Erebus* fell overboard and could not be saved, the Giant Petrels swooped at him as he struggled to keep afloat, and it is doubtful if they did not actually strike him with their bills; while Mr. Arthur G. Guillemard states that a sailor, who was picked up, had his arms badly lacerated in defending his head from the attacks of an 'Albatros,' which may well have been this Giant Petrel.

Of the small grey Prions, with broad boat-shaped bills, known to sealers as 'Whale-birds,' only one, the BROWN-BANDED PETREL of Latham (*Prion desolatus*), appears to reach the edge of the Antarctic circle—an example having been obtained by the *Challenger* at the ice barrier on 14th February 1874. This species is found over the eastern portion of the Southern Ocean, to 30° S., and its breeding habits at Kerguelen have been described by the Rev. A. E. Eaton, Moseley, and others. Three others, *Prion vittatus*, *P. banksi* and *P. ariel*, have not been recorded to the south of lat. 60°, but otherwise they have a similar longitudinal range.

After the Penguins and some of the Petrels, the most prominent species within the Antarctic circle is a predacious and aggressive Gull, MCCORMICK'S SKUA, named after its virtual discoverer.

several days, hovering about us as if he had lost himself, till Hatley (my second Captain) observing, in one of his melancholy fits, that this bird was always hovering near us, imagin'd, from his colour, that it might be some ill omen. That which, I suppose, induced him the more to encourage this superstition, was the continued series of contrary tempestuous winds, which had oppress'd us ever since we had got into this sea. But be that as it would, he, after some fruitless attempts, at length shot the *Albitross*, not doubting (perhaps) that we should have a fair wind after it'! In the second edition (1757) this story is spoiled by compression.

It was first obtained at Possession Island, Victoria Land, where a pair had taken up their residence in the midst of a colony of the Adélie Penguins, and subsequently examples were obtained or seen nearly as far south as 78°, while long. 178° W. was the furthest record in the direction of America. The *Belgica* brought back four examples (which I have examined) from about 70° S. and between 82° and 86° W., in the ice pack. The *Southern Cross* obtained a fine series, from the downy nestling upwards; these young birds being of a dark slate-grey, and very different from those of the other Great Skuas, of which four representatives are now recognised. The species known as the 'Bonxie,' of the Shetlands, frequenting the North Atlantic, is not known to the south of the coast of Morocco; but in the Southern Ocean, from the New Zealand area to Heard, Kerguelen, Marion and Crozet Islands, and westward to the Falklands, is found a larger and darker bird (*Megalestris antarctica*), which seems to breed as far as the South Shetlands and Cockburn Island, and I have examined a specimen obtained by the Dundee whalers. Some six or seven degrees of latitude separate this dark form from McCormick's Skua, which is a much paler bird, almost dirty straw-colour about the head and neck. The fourth species, *M. chilensis*, has the under parts of a warm chestnut colour. Further specimens of these Southern Skuas, with notes on their geographical distribution, are much wanted, but anything approaching the extermination of a colony is to be deprecated.

A Gull which approaches the Antarctic circle is the Southern Black-backed Gull (*Larus dominicanus*), which is recorded by McCormick as breeding at Cockburn Island, and was obtained by Capt. Fairweather, of the *Balæna*, in 64° 18′ S. Northward, it is widely distributed on the coasts of South America and South Africa, and nests on most of the islands from the South Shetlands to the Falklands and South Georgia, and eastward—omitting Tristan da Cunha—to the Prince Edward, Crozet, Kerguelen and Heard Islands, and so to the New Zealand area.

It is also to Capt. Fairweather, of the *Balæna*, that the British Museum is indebted for by far the most Southern example of another and very remarkable Gull, from the vicinity of the South Shetland Islands, in 64° 55′ S., whence it was originally described by Traill,* namely *Larus scoresbii*. This species has a very stout crimson bill; head, neck and under parts of a lavender grey, and a black mantle; but the curious part about it is, that in the immature stage it has a very marked sooty hood, which gives it a superficial resemblance to

* 'Mem. Wern. Soc.,' iv. p. 114, 1823.

a Saddle-backed Crow. It is a very localised and terrestrial Gull, feeding largely on the eggs and young of other species, molluscs, etc.; and ranging to the Falkland Islands, South Georgia Island and Patagonia, on the east side, and through the Straits of Magellan, up to the Island of Chiloe, in the Pacific.

There is ample evidence that TERNS are found in large numbers in the South Polar regions, and even within the Antarctic circle, for Bellingshausen, of the Russian ship *Wostok*, has recorded Terns, on 18th February 1820, in 68° S., while McCormick saw one in 76° 52′ S. and 178° W., and he had previously observed 'flocks' on the ice between 65°–66° S. and in about 158° W. On the third attempt of the *Erebus*, McCormick noticed Terns breeding on Cockburn Island; Webster found birds of this family in the South Shetlands; and the Dundee whalers brought back specimens from that neighbourhood, which are referable to a well-known South American species, *Sterna hirundinacea*, akin to our own Common Tern, though quite distinct. This distribution might be expected, and it may be reasonably assumed that all the Terns found to the southward of America are of this species. But the species found off Victoria Land has still to be identified, and all that can be said is that, inasmuch as the *Southern Cross* expedition obtained at Campbell Island an adult of *Sterna vittata*, there is a probability that this species may go as far as Victoria Land. This latter, the 'Wreathed Tern' of Latham, breeds in the volcanic islands of St. Paul and Amsterdam, and occurs at Christmas Harbour, in the north of Kerguelen; but the characteristic Tern of the last-named island, as well as of the Crozets, and probably of Heard Island, is a more sooty-coloured species, *S. virgata*. Further details would be technical and tedious, but enough has been said to show the importance of securing specimens of this family on the Antarctic Expedition from as many localities as possible, in order that they may be identified by experts.

Almost the last species which call for notice are the Sheathbills (*Chionididæ*), belonging to the order Limicolæ. They are white birds about the size of pigeons, and are generally so called by the sealers. The Lesser Sheathbill (*Chionarchus minor*) inhabits Kerguelen and Heard Islands, and also Marion and Prince Edward Islands; while on the Crozets, which are, roughly, halfway between Kerguelen and the Prince Edward group, there is a slightly smaller form, which Dr. Bowdler Sharpe considers specifically distinct. I do not know if any kind of Sheathbill is found on the South Sandwich or the South Orkney Islands; but on South Georgia Island, the Falklands,

and along the extreme south of America, reaching down to the South Shetlands, Louis Philippe Lands and Joinville Island, 64° S., is found a larger species, *Chionis alba*, with caruncles or wattles at the base of the bill, which the eastern species has not. The Sheathbills lay two or three eggs in the crevices of the rocks, or under herbage; the colour of these being creamy-white, blotched and streaked with purplish-brown and slate-colour. The bird feeds largely upon the eggs and nestlings of other birds, droppings and other refuse, as well as crustaceans, etc.*

Lastly, there is a Cormorant of some kind which Webster, of H.M.S. *Chanticleer*, calls 'the Blue-eyed Shag,' found breeding at Deception Island, South Shetlands; McCormick records a resting-place of Cormorants on Cockburn Island; and the naturalists in the Dundee whalers seem to have met with some bird of this kind. At present there seems no clue to the species.

APPENDIX TO BIRDS.

APTENODYTES FORSTERI. Grant, Cat. B. Brit. Mus. xxvi. p. 626. Emperor Penguin (p. 225).

Upper parts bluish-grey; head to throat black, with a yellow patch on each side of the head shading into white on the neck; under parts white. In the young bird the throat is nearly white, and there are little signs of yellow patches. Length up to 45 in.

Aptenodytes patagonica. Grant, Cat. B. Brit. Mus. xxvi. p. 627. King Penguin (p. 225).

Aptenodytes longirostris of some authors, i.e. Moseley, *Notes Nat. 'Challenger.'*

Upper parts generally as in the above, but shading into pearl-grey on back of the neck and shoulders; crown of head, cheeks and

* The circumstantial account in the 'Ibis,' 1895, p. 165, of the shooting of this species in 78° S. by 'the late Dr. W. Gunn, R.N., Surgeon of H.M.S. *Terror*, in the Antarctic Expedition,' must be due to an error of memory. In an official letter from the Admiralty it is stated 'that the name of William Gunn does not appear in the pay-books of the *Erebus* or *Terror* for the period of the Antarctic Expedition, 1839-43, but that a Naval Surgeon of that name was serving in H.M.S. *Curaçoa* and *Crescent* on the South American Station during that period.' Dr. McCormick expressly states that no Sheathbill of any kind was seen from the time the Expedition left Kerguelen in 1840, until the 2nd-3rd April 1842, when approaching the Falklands; and the independent testimony of Ross is confirmative.

chin black, with orange-yellow bands which nearly meet on the nape, run below the black throat, and widen on upper breast. Under parts white. The immature bird has little yellow. Length 36 in.

PYGOSCELIS ADELIÆ. Grant, Cat. B. Brit. Mus. xxvi. p. 632. Adélie Land Penguin (p. 227).

Bill rather stout and blunt. Upper parts slate-grey; sides of the head, chin and throat, dull black; under parts pure white. Length 30 in.; weight about 10 lbs. In the immature bird the throat is white.

Pygoscelis papua. *Id.* t.c. p. 631. (*P. tæniatus* of Coues, Scl. and Salv., Moseley, &c.) 'Gentoo' or 'Johnny' (p. 227).

Similar to above, but with a white band across the crown from behind the eyes. Length 30 in.

Pygoscelis antarctica. *Id.* t.c. p. 634. Ringed or Bridled Penguin (p. 227).

Similar, but the grey of the upper parts bluer than in preceding species; throat white, with a thin blackish 'bridle' from under the chin, ear to ear. Length 30 in.

Catarrhactes chrysocome. *Id.* t.c. p. 635. 'Gorfoo' or 'Rock-hopper' (p. 227).

Upper parts dark slate-colour; top of the head black, with a crest of feathers elongated to 3 in.; a golden-yellow eyebrow stripe of similarly elongated feathers along the sides of the crown; cheeks, chin and throat dull black; rest of under parts white. Length about 30 in.

Catarrhactes chrysolophus. *Id.* t.c. p. 641. 'Macaroni Penguin' (p. 228).

Generally similar to above, except that the yellow eyebrow stripes are wider and join on the forehead. Length 30 in.

Spheniscus magellanicus. *Id.* t.c. p. 651. Jackass Penguin (p. 228).

Bill rather long and stout. Forehead, crown and nape black, shading into slate-grey on the rest of the upper parts; chin, throat and cheeks black, with broad white stripes enclosing the last, and a broad black band across the white breast. Length about 28 in.

OCEANITES OCEANICUS. Salvin, Cat. B. Brit. Mus. xxv. p. 358. Wilson's Storm Petrel (p. 228).

Sooty-black above and below, the quills and tail feathers darker black; greyish-white edges to the wing coverts and inner secondaries; upper tail coverts and thigh patches white; black bill, legs and toes,

the webs yellow at their bases. Length 7 in., wing 6 in., tarsus 1·4 in.

THALASSŒCA ANTARCTICA. *Id.* t.c. p. 392 (p. 229).

Head and mantle brown, with broad white edges to wing coverts and secondaries; tail white, tip brown; under parts white. Length 17 in., wing 12 in.

THALASSŒCA (PRIOCELLA) GLACIALOIDES. *Id.* t.c. p. 393. (p. 230).

Head and neck pale grey, mantle rather darker; quills brownish on outer webs, tail pale grey. Length 18 in., wing 12·6 in.

Majaqueus æquinoctialis. *Id.* t.c. p. 395. 'Cape Hen,' 'Black Night Hawk,' 'Black Eaglet.'

Sooty black, with a very variable amount of white on the chin and upper throat, sometimes round the eye, and almost across the crown; the white seems to be most prevalent in Australian and New Zealand waters. Length 20 in., wing 15 in.

PAGODROMA NIVEA. *Id.* t.c. p. 419. Ice Petrel (p. 229).

Pure white; bill black; feet yellowish. Length 14–16 in., wing 9·8–11 in., the difference in the size of individuals being remarkable.

OSSIFRAGA GIGANTEA. *Id.* t.c. p. 422. GIANT PETREL, 'Nelly' (p. 230).

The adult is uniform dark chocolate-brown, but immature birds exhibit more or less white in their plumage, while nearly white individuals are not uncommon. Length 34 in., wing 20·5 in., bill 4·2 in.

DAPTION CAPENSIS. *Id.* t.c. p. 428. CAPE PETREL, 'Cape Pigeon' (p. 230).

Head, neck and throat blackish; feathers of the mantle mainly white, but tipped with black,* tail broadly tipped with black; under parts white. In the young the black has a browner hue. Length 16 in., wing 10·5 in.

Prion desolatus. *Id.* t.c. p. 434. Brown-banded Petrel (p. 231).

Upper surface ashy-blue, darker on the head; a distinct whitish eye-stripe; a black band across the mantle; under surface white; bill blue-black, the tail yellow, tarsi and toes light blue. Length 12 in., wing 7·6 in.

* To its 'chequered' appearance, like the black and white squares of a draught-board, the bird is indebted for its French name, *Damier;* its Spanish equivalent is *Pintado.*

Diomedea, sp. ? See footnote, p. 230.

Phœbetria fuliginosa. Salvin, Cat. B. Brit. Mus. xxv. p. 453. Sooty Albatros (p. 230).

Plumage generally sooty, paler and greyer on the shoulders and the under surface; an imperfect white ring round the eye; tail rather long and wedge-shaped; bill black, with an orange-yellow groove. Length 36 in., wing 19·5 in.

This bird, the 'Piow' or 'Peeo' of the sealers, has a wide range in the Southern oceans. It is known to breed on South Georgia, the Prince Edward and Marion Islands, the Crozets and Kerguelen; but further information respecting the haunts of this and every other Albatros is much to be desired. There are in all fifteen species of Diomedeidæ, but no other than the above is known to make a near approach to the Antarctic Circle.

Megalestris antarctica. Saunders, Cat. B. Brit. Mus. xxv. p. 319 (p. 232).
MEGALESTRIS MACCORMICKI. *Id.* t.c. p. 321, pl. 1 (p. 231).

The Antarctic Skua, known to seafaring men as the 'Port Egmont Hen' and 'Sea Hen,' is of a dark brown colour, paler on the under surface, and with white bases to the outer primaries, forming a fairly conspicuous bar when the wing is extended. The largest specimens, attaining a length of 24 in., and wing 17 in., have been taken in the New Zealand area; the smallest are from the vicinity of the Falklands, and have an average length of 21 in., wing 15 in. McCormick's Skua is much paler, the crown being olive-brown; the acuminate feathers of the neck strongly marked with golden straw colour, and the upper breast streaked with the same, though in a less degree; the remaining under surface darkening to coffee-brown on the belly; mantle, wings and tail chiefly umber-brown, as in the preceding. Both species—and, indeed, all the Skuas—have exceedingly sharp curved claws, like those of Accipitrine birds.

Larus dominicanus. Saunders, Cat. B. Brit. Mus. xxv. p. 245 (p. 232).

The Southern Black-backed Gull has the head, neck, tail and under surface pure white; the mantle sooty black; the wing feathers mainly blackish, with white sub-apical patches or 'mirrors,' which increase in extent with the maturity of the individual; bill yellow, red at the angle; tarsi and toes greyish-olive, with yellower webs. Average length of the male 23 in., wing 16·5 in.; the female rather smaller. Campbell Island is the furthest south known in the New Zealand area, but the species may reach the Macquarie group.

Larus (Leucophæus) scoresbii. *Id.* t.c. p. 299 (p. 232).

The plumage of this species has been already described. Length 18 in., wing 13·25 in. It is not likely that the bird will be found outside Weddell Quadrant.

{ *Sterna hirundinacea.* *Id.* t.c. p. 53 }
{ *S. vittata.* *Id.* t.c. p. 51 } (p. 233).

Little of value can be added to the remarks on p. 233. These Terns, the 'King-birds' of sealers, have all of them crimson bills and feet, black crowns, grey mantles, and paler under surfaces; but the rump in *S. vittata* is grey, while in *S. hirundinacea* (the larger) it is nearly white. *S. virgata*, of South Kerguelen, is darkest of all; and, restricted to New Zealand, is found a fourth species, *S. albistriata*, with yellow bill, legs and feet.

Chionis alba. Sharpe, Cat. B. Brit. Mus. xxiv. p. 710. Wattled Sheathbill (p. 234).

Phalacrocorax, sp. ? Cormorant (p. 234).

XVII.

ZOOLOGY:

ANTARCTIC DEEP-SEA FISHES.

By G. A. Boulenger, F.R.S.

As the meagre information to hand up to quite recently is to be found in the general works of the *Challenger* Expedition and Goode and Bean's 'Oceanic Ichthyology'—the latter being recommended for its general scope and portable form—it will suffice to mention that the only collection made since the publication of these works, that of the *Belgica*, has yielded very few fishes. Up to the present, three short preliminary reports have been issued in the 'Bulletin de l'Académie royale de Belgique' for 1900, in which M. L. Dollo has described three new species obtained by that expedition, each being regarded as the type of a new genus :—

Cryodraco antarcticus (Fam. *Trachinidæ*).
71° 22'. Lat. S. by 88° 38'. Long. W., 450 metres.
Gerlachia australis (Fam. *Trachinidæ*).
71° 34'. Lat. S. – 89° 10'. Long. W., 500 metres.
Racovitzia glacialis (Fam. *Trachinidæ*).
71° 23'. Lat. S. – 87° 32'. Long. W., 435 metres.

Although the species may not be numerous, yet the individuals may, and in such cases the importance is urged of bringing home large series, which should be of use both for adding to the knowledge of individual variations, and for making investigations on the anatomy. Most of the deep-sea fishes are known from single or scanty specimens only, and many are the generic forms the anatomy of which is absolutely unknown through want of material that can be sacrificed. If, therefore, the Expedition is provided with an ample supply of alcohol, the formation of good series of individuals is in every case to be recommended. In fact, in regions such as those that will be visited, it might even be recommended to preserve every specimen not brought up in too bad a condition.

This might perhaps be done without too much expenditure of spirits, if the supply be a limited one, by preserving some of the duplicates in formaldehyde, or formol, as it is frequently called. This fluid, which is strongly recommended for the preservation of some groups of invertebrates, is invaluable from the fact that, such as it is supplied by the trade, it may be diluted with 25 volumes of water. But the results, so far as fishes are concerned, have not proved satisfactory. It has these drawbacks:—1. That it hardens the tissues, stiffens the fins, practically "sets" the specimens, and renders them brittle when manipulated; 2. That the fluid is more or less unstable, and, when exposed to light, produces an acid solution, the effects of which may be actually to decalcify the bony tissues. I therefore strongly recommend the use of spirit of wine at 20° over proof for the preservation of the first set of specimens, formol to be employed only for duplicates if reasons of economy should at all warrant its use.

Sharks may be found in some abundance. Suffice it to say that our knowledge of them is still very incomplete. Their preservation in brine should offer no difficulty in a cold climate; large specimens, that is, over 4 feet, to be preserved as skins, rolled up over the head, which may be left intact, and packed in barrels filled with salt.

XVIII.

ZOOLOGY:

ON THE ABYSMAL FAUNA OF THE ANTARCTIC REGION.

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THE area I have selected in the following essay* is, roughly speaking, a triangle, the apex of which is situated on the 80th meridian of E. longitude, almost exactly south of Ceylon, at a latitude of 65° 42′ S., a little north of the Antarctic circle. Here the southernmost dredging of the *Challenger* was taken. The western leg of the triangle, stretching by way of Heard Island, Kerguelen, the Crozets, to Prince Edward and Marion Islands, reached station 146 of the *Challenger* expedition,† a little to the west of the last-named islands, in lat. 46° 46′ S. and long. 45° 3′ E. The eastern leg extended to station 159, nearly south of Adelaide, and a little north of the 50th parallel. The depth of the sea in this area varies between 1000 and 2000 fathoms. It will be noticed that the angle described practically subtends the whole of the Indian Ocean.

Although the waters in the region are cold, and may be termed sub-antarctic, the wealth of life in the ocean is abundant.‡ After passing lat. 50 S. enormous quantities of Diatoms are recorded in the surface waters, and with the Diatoms were Radiolaria. The spoils of

* In the preparation of part of this essay I was greatly helped by my friend Mr. C. Crossland, of Clare College, Cambridge.

† At the end of this article will be found a list of the stations mentioned in our area, their position, the temperature of the water at the surface and on the bottom, the nature of the ocean floor and the depth of the sounding. A further list of the positions of the stations mentioned, but not included in the district, is also added.

‡ In the systematic part of this essay I have considered the various phyla of the Invertebrate Metazoa that occur in the Antarctic deep seas, and the Tunicata. I have omitted the Protozoa, since these animals come better under the heading of deposits of the ocean floor.

the dredge at station 146 were "probably the most successful haul up to the present date, as regards number, variety, novelty, size and beauty of the specimens," and the results of the soundings at station 147 were even richer. Sir John Murray says "the deep-sea fauna of the Antarctic has been shown by the *Challenger* to be exceptionally rich, a much larger number of species having been obtained than in any other region visited by that expedition, and the *Valdivia's* dredgings in 1898 confirm this." The *Valdivia's* course was, roughly speaking, parallel to that of the *Challenger* in these waters, but further west. The most southern point it reached, the apex of its angle, was about long. 55° E., off Enderby Land. The results of this expedition are being worked out, but are not yet available.

It must not be overlooked that the dredge, probably in all cases, certainly in many, brought on board numerous forms which had no acquaintance with the deep-sea bottom. In its lengthy and slow passage from the depths it enmeshed many a dweller of the middle regions, and as it passed from water into air it skimmed the surface fauna. A striking instance of this occurred at station 158, where the dredge brought on board the remarkable Nemertine *Pelagonemertes rollestoni* Moseley, whose very tissues proclaimed its pelagic or sea-surface origin. In the systematic part of this essay the species of animal brought up in the dredge from great depths are recorded one by one, and although it is impossible to be certain in every case that they really come from the bottom, their habits and their relationship to other bathybial forms makes this, in the great majority of cases, a matter of no doubt.

The conditions of life in the ocean at depths over 1000 or 2000 fathoms are remarkably uniform, and although the "abysmal depths of the Antarctic Seas" sound colder than those of the tropics, they have really all about the same temperature, i.e. a few degrees above the freezing point of fresh water. It is possible that near the Poles this temperature may be a degree or two below 32° F., but the change of two or three degrees in the surrounding medium probably has no more effect on abysmal organisms than a change of from 62° to 64° or 65° F. has on us.

The waters are still. Compared with the shallow seas there are no currents; and though we know that in places strong currents destroy deep-sea cables, and that there must be a continuous though slow change of water over the floor of the ocean, otherwise the waters of the tropics would become heated at the depths, yet, compared with the surface of the earth and with the shallower seas, we may look upon the depths of the ocean as a place where a great calm

reigns. One result of this may be the interesting fact, that in certain sessile animals, whose "strength is to sit still," such as the Monaxonid Sponges, a perfectly definite symmetry of form is developed, and they differ in this from their shallow-water allies, which are exposed to varying currents and conditions, and which are of any shape provided only it be asymmetrical. Curiously enough, the absence of movement seems to produce the contrary effect in certain radial but non-sessile animals. The Holothurians of the shallow seas, rolled about in the varying tides, turn now one radius now another, to the substratum. But the Holothurians of the deep, the *Elpidiidæ*, unmoved by ebb or flow, presenting one face perpetually to the bottom, have developed a secondary bilateral symmetry, and protrude their tube-feet from one surface alone.

No light from the sun penetrates the deep sea. There is no day and night. In connection with this absence of light from without certain animals, notably the Fishes, Crustacea, some Echinoderms, and Worms, have developed phosphorescent organs, but the part they play in illuminating the depths can hardly be greater than that of the policeman's bull's-eye in lighting up London during a November fog. Corresponding with this darkness, lit up by an occasional phosphorescent flash, the animals of the depths have either lost, or are losing, their visual organs, or have developed enormous eyes. With the absence of light may again be associated the uniformity of colouring of the denizens of the depths. Many of them are brightly coloured; reds abound in the Crustacea, purple and green in the Holothurians, yellow and browns in the Crinoids, violet and orange in the deep-sea Medusæ; a large number are uniformly white or whitish-yellow, or grey, and sometimes black; blue alone is rare. It has been suggested by more than one observer that the colours of some animals, e.g. the Crustacea, change as they are dragged up from the bottom to the surface and that some of the bright red forms as we see them are in the abysses of the ocean of a blue colour. But, whatever be the colour, it is, as a rule, uniform, and there is a marked absence of those bands, stripes and spots, which play so large a part in the life of dwellers on the land or in the shallow waters. The large size attained by certain groups, such as the Isopods, seems to be more nearly associated with a polar distribution than with the great depths.

In the abysses of the ocean there is no sound. The organs which in Invertebrata are usually associated with the perception of sound, as a rule only reach a high degree of development in those forms which move actively about, and it is most probable that they act as balancing organs, not as hearing organs. The necessity for organs

by means of which a moving animal determines its position in relation to the surroundings is as great at two thousand fathoms as at twenty, and, as far as is known, these organs have, as a whole, suffered no degeneration.

If we could see the bottom of the deep sea, we should see, except in those few places where a current is active, a uniform layer of what we should call fine mud lying like a thick deposit over the bottom of the ocean, covering rock and stone. This is caused by the tireless fall of the skeletons of minute organisms which abound in the surface of the sea. In comparatively shallow waters, where the calcareous shell can reach the bottom without being dissolved in transit, this deposit is the *Globigerina* ooze; in deeper waters the siliceous framework of Radiolaria or Diatoms forms the deposit. It is ceaselessly, though very slowly and very gently, falling through the water. It is, perhaps, connected with this layer of deposit that so many members of the Benthos,* whose allies are sessile in shallower seas, are stalked, or if their allies be stalked, in the depths they have acquired longer stalks. Instances of this occur in the Sponges, the Alcyonarian *Umbellula*, the stalked Crinoids, the Tunicata, and other groups.

Certain curious features occur over and over again in deep-sea creatures for which there seems no obvious reason. There is an inexplicable inability to deposit much calcareous matter in the skeleton, whether internal or external. The bones of many deep-sea fishes are deficient in lime, and remain either membranous and fibrous or cartilaginous; the shells of certain molluscs are "as tissue paper;" the test of some Echinoids is soft, with at most certain detached calcareous plates; the exoskeletons of the Crustacea remain, as a rule, chitinous; calcareous sponges are not found. This state of things cannot be due to the absence of calcium carbonate, for we know that the calcium sulphate, from which the carbonate is formed, is present in abundance, and, moreover, the deficiency in lime occurs as commonly in those creatures living on the calcareous *Globigerina* ooze as it does in those which live in the siliceous Radiolarian deposits. On the other hand many animals such as the Radiolaria which secrete silex have unusually stoutly developed skeletons at great depths.

Possibly, connected with this deposit of sediment is the fact, that in many of the creatures who have retained their eyes these organs are borne at the end of long stalks. The Podophthalmous Crustacea tend to become more Podophthalmous, and some of the bathybial fishes carry their eyes at the tips of long lateral prolongations of the

* A term introduced by Haeckel to denote those marine animals which do not swim about or float, and which live on the bottom of the ocean either sessile or creeping about.

head. In those animals which have, so to speak, followed an evolutionary path in the opposite direction, and, instead of evolving immense eyes, have suppressed eyes altogether, their place has to some extent been taken by a great development of tactile organs. Antennæ, "barbels," and tentacles lengthen, and in some cases, e.g. some species of Pycnogonid, the legs are enormously elongated, and probably act as sensory outposts.

Another of the peculiarities for which it is difficult to assign an adequate reason, is the change that the respiratory organs undergo in many abysmal forms. In Crustacea, Mollusca and in Fishes, there is often a marked reduction in the size and number of the gill-filaments, and in many Tunicata the branchial chamber is profoundly modified. In the Isopod *Bathynomus*, on the other hand, the normal respiratory organs of the abdominal appendages have been replaced by branching outgrowths of the body-wall full of blood. These are protected by the abdominal appendages, which act as opercula.

All deep-sea animals are carnivorous, and must be so, as no vegetation flourishes in the dark depths of the ocean. Correlated with this diet is the large mouth and development of efficient organs for capturing prey, and on the other hand, a certain "spiny-ness" which is apt to appear in many forms which elsewhere are comparatively smooth. The development of these spines may be somewhat of a protection against the large mouths just mentioned. Perhaps, more than elsewhere on the earth, the depths of the sea bear evidence to the truth of the Frenchman's summing up of Life as the conjugation of the verb "I eat," together with its terrible correlative "I am eaten."

It seems probable that most of the bottom dwellers of the Polar seas undergo a direct development; at any rate there is a great absence of pelagic larvæ which might belong to them in the surface waters. And in the case of certain Crustacea and Echinoderms from the colder waters of both hemispheres such a direct development has been observed.

The Benthos, or abysmal fauna, like the Plankton, or surface and swimming fauna, of the Antarctic, contains a number of species and genera which are again met with in Arctic circles, but are unknown in the intervening oceans. This peculiarity is a factor of the whole marine fauna, and not of the deep-sea forms only, and will therefore not be further considered here.

When deep-sea exploration was first undertaken it was thought, or at any rate hoped, that the sea would give up many an old-world form—living examples of what we know only as fossils—and that the abysses of the ocean would yield many a missing link. This has

hardly proved to be the case. On the whole the inhabitants of the depths prove to be closely connected with fauna of the shallower waters. Still some interesting forms have been found. *Cephalodiscus dodecalophus*, M'Int., taken by the *Challenger* in the Straits of Magellan, has thrown some light on the more primitive members of the Chordate phylum. The existence of the stalked Crinoids, otherwise only known as fossils, of the deep-sea Medusæ, to which Haeckel attributes an archaic structure, of the remarkable forms of deep-sea Holothuroids and Tunicates, go far to fulfil the hopes with which the voyage of the *Challenger* set forth. Whilst many deep-sea forms belong to the same families, and even to the same genera, as their shallow-water allies, and have probably descended to the depths in comparatively recent times, the existence of the large groups just mentioned, found as a rule in no other zones, shows that ages ago certain forms migrated to the abysses of the ocean. There, undisturbed by the fret of tide or current, in quiet and gloom, they have developed into new forms, which are as characteristic of the depths of the great Ocean as a mountain-fauna is of the Alpine heights.

SYSTEMATIC PART.

PORIFERA.

The first class of the Sponges, the CALCAREA, is unrepresented in the deep seas. None have been found at a greater depth than 450 fathoms, and in our region the deepest were *Amphoriscus elongatus*, Pol., and *Leuconia levis*, Pol., at 150–310 fathoms, station 145. The absence of the calcareous forms may be connected with the extreme difficulty of secreting lime which appears to obtain in the depths of the ocean, a difficulty which is shown by the thinness and tendency to disappear of the calcareous shell in molluscs and crustacea, of the test in echinoderms, and in the softness of the bones of deep-sea fishes.

The KERATOSA, or Horny Sponges, are likewise not a deep-sea group, and are not found at a greater depth than 400 fathoms, except certain families described by Haeckel and not universally accepted. None of these are found in our district.

The HEXACTINELLIDA found in the depths of the Antarctic region are as follows:—Belonging to the family *EUPLECTELLIDÆ*, (i.) *Holascus fibulatus*, F.E.S., from stations 146 and 147, and outside the area

from station 160, off Tasmania; (ii.) *H. polejaevii*, F.E.S., from station 157; (iii.) *Malacosaccus vastus*, F.E.S., from station 146, a "flabby plate" which "could be folded like a cloth." Belonging to the family Asconematidæ, (iv.) *Polyrhabdus oviformis*, F.E.S., from station 156; (v.) *Caulophacus latus*, F.E.S., from station 147. Belonging to the family Rossellidæ, (vi.) *Rossella antartica*, Carter, first described from specimens brought home by Sir James Ross, was taken by the *Challenger* at stations 145 and 150, and again off Buenos Aires; (vii.) *Bathydorus spinosus*, F.E.S., from station 147; (viii.) *Aulocalyx irregularis*, F.E.S., from stations 147 and 145 and from station 56, south of the Bermudas. Belonging to the family Hyalonematidæ, (ix.) *Hyalonema conus*, F.E.S., from station 158; (x.) *Stylocalyx clavigerum*, F.E.S., from station 147. Belonging to the family Farreidæ, (xi.) *Farrea*, sp., from station 147. Belonging to the family Coscinoporidæ, (xii.) *Chonelasma lamella*, F.E.S., from station 148, and from the same station (xiii.) *Hexactinella*, sp., belonging to the family Tretrodictyidæ. The deep-sea members of this group possess some of the most beautiful skeletons found amongst Sponges.

The deep-sea Monaxonida differ from the shallow-water members of the group in that whereas the latter are without any definite symmetrical form, "in the abyssal species a perfectly definite and usually symmetrical external form is almost invariably present." The following bathybial species were found in our region:—(xiv.) *Esperella mammiformis*, R. & D., the soft parts crowded with Diatoms; (xv.) *Esperiopsis profunda*, R. & D.; (xvi.) *Cladorhiza tridentata*, R. & D.; (xvii.) *Meliiderma stipitata*, R. & D. The four genera just mentioned belong to the family Desmacidonidæ, and all of them, together with the two genera which follow, were taken at station 147; (xviii.) *Axinella erecta*, R. & D., of the family Axinellidæ, a very variable and very widely distributed species; it has been taken between the Faröe Islands and the Shetlands, as far south as station 147, and at many intermediate points; (xix.) *Stylocordyla stipitata*, Carter, of the family Suberitidæ, like the preceding species, extends throughout the Atlantic, and its bathymetrical range is also very extensive, extending from 7 to 1600 fathoms; (xx.) *Cladorhiza moruliformis*, R. & D., was taken at station 157. Of the preceding genera, *Cladorhiza*, *Meliiderma* and *Stylocordyla* are characteristically deep-sea forms, which are rarely or never met with in shallow water.

Of the Tetractinellida only one species was taken at any great depth in our area:—(xxi.) *Thenea delicata*, Sol., of the family Theneidæ, was taken at station 147.

CŒLENTERATA.

Class I.—HYDROMEDUSÆ (CRASPEDOTA).

(A.) LEPTOMEDUSÆ-CALYTOBLASTEA. But few *PLUMULARIIDÆ* are deep-sea; the genus *Cladophorus* has, however, been dredged from depths as great as 900 fathoms off the Azores. In our region (i.) *Plumularia insignis*, Allm., was taken at station 145 at depths of 150 and 310 fathoms, and one or two other species occurred at a less depth. Numerous other species of Leptomedusæ were taken in shallow waters, mostly under 100 and none over 150 fathoms.

(B.) ANTHOMEDUSÆ-GYMNOBLASTEA. Hydroid forms were not met with in the depths in our area, but a deep-sea Medusa, (ii.) *Thamnostylus dinema*, Haeck., of the family *THAMNOSTOMATIDÆ*, was taken at station 153, and although the depth was only 150 fathoms, it deserves mention as being taken at the most southern locality where dredging took place. This species has a remarkable development of the oral organs, a long œsophagus and four much branched oral processes of a blood-red colour. The branches, amounting to more than a thousand, terminate in stinging knobs. Only two marginal tentacles are developed.

(C.) HYDROCORALLINÆ are not represented by any specimens dredged by the *Challenger*, but the following species have been recorded at other times, from the Antarctic Ocean; (iii.) *Errina fissurata*, Gray; (iv.) *Labiopora antarctica*, Gray.

(D.) TRACHYMEDUSÆ are represented by (v.) *Pectis antarctica*, Haeck., of the typical abysmal family *PECTYLLIDÆ*. The single specimen obtained was taken at station 152. The whole umbrella edge is beset with sucking tentacles. The œsophagus has 8 adradial, ectodermal, oral funnels alternating with 8 endodermal pouches, an arrangement peculiar to this genus. The *PECTYLLIDÆ*, like many abysmal Medusæ, are deficient in sense-organs. It has been suggested that they walk about on the ends of their curiously-knobbed sucking-tentacles.

(E.) NARCOMEDUSÆ have but one deep-sea Medusa from our area, (vi.) *Æginura myosura*, Haeck., of the family *ÆGINURIDÆ*, taken at station 159, one specimen only.

(F.) SIPHONOPHORA, represented by (vii.) *Disconalia pectyllis*, Haeck., taken at station 157, and interesting as one of the Siphonophora which has a very medusoid shape and characters. It is a member of the family *DISCALIDÆ*, which Haeckel unites with the familes *PORPITIDÆ* and *VELELLIDÆ* in the group DISCONECTÆ.

Class II.—Acalephæ (Acraspeda).

The Schyphomedusæ are represented by two species in our region. (viii.) *Periphema regina*, Haeck., of the family *Periphyllidæ*, of the sub-order Peromedusa. It was taken in fragments at station 156, and was a very large form, measuring 180–200 mm. in diameter. (ix.) *Atolla wyvillii*, Haeck., one of the family *Ephyridæ* of the sub-order Discomedusæ, taken at station 157, and again in the South Atlantic at station 318, is one of the most interesting Medusæ brought home by the *Challenger*. Haeckel regards it as the remains of an extinct ancestral form of the Discomedusæ and as indicating the close connection of this group with the Peromedusæ and Cubomedusæ.

Of the eighteen deep-sea Medusæ described by Haeckel, it thus appears that six, or one-third, have been captured in the Antarctic region. It is, of course, not absolutely certain that all the specimens were taken at the depths. Some may have entered the dredge in its way upwards. Still, Haeckel thinks that of the genera just mentioned, *Pectis* and *Æginura* amongst the Hydromedusæ, and *Periphema* and *Atolla* amongst the Scyphomedusæ, have characteristics which suit them to an abysmal mode of life; and moreover, that they show by their primitive structure a remote phylogenetic origin. The families to which these genera belong have probably been deep-sea dwellers for a very long period of time.

Class III.—Actinozoa.

(A.) Alcyonaria.

The sub-order Pennatulacea, the most highly organised is at the same time the most typically bathybial of the five Alcyonarian subdivisions. They are rarely met with in shallow water, and at least one-half of the genera described are deep-sea forms. Two families, the *Umbellulidæ* and the *Protoptilidæ*, are characteristically abysmal, but the latter is not represented in our area. The family *Umbellulidæ* is represented by (x.) *Umbellula carpenteri*, Köll., taken at stations 156 and 157. The axial polype is, in this family, drawn out to form an enormously long stalk, a characteristic feature of many deep-sea animals (c.f. the stalked Crinoids and Tunicata). (xi.) *U. magniflora*, Köll., from station 147, attained a total length of 740 mm. The genus *Umbellula* has the widest distribution of all the Pennatulids, stretching along the Atlantic and Pacific from pole to pole.

Of Alcyonarians, other than Pennatulids, two deep-sea species

were found. (xii.) *Callozostron mirabilis*, Perc. Wright, of the family *Primnoidæ*, was dredged at the southernmost station, 153. This species apparently lives prostrate in the mud; (xiii.) *Thouarella antarctica* (Val.), of the same family, was taken at station 148A, at 550 fathoms. A good many other species were found in the area, but seldom below 150 fathoms and never below 350 fathoms. Hence they are not included here.

(B.) Zoantharia.

(i.) Actiniaria. Numerous species of many families of sea-anemones have wandered into the abysmal depths of the ocean, but there are no entirely deep-sea families, and hence it seems probable that the Actiniaria of the great depths are comparatively recent denizens of that part of the earth's surface. They have not developed many peculiar characters. Perhaps the most striking is the tendency for the tentacles to diminish in size, and to be replaced by a row of holes (representing their terminal pores) surrounding the mouth. It must not be overlooked, however, that these holes are, in all probability, caused by the artificial breaking off of the tentacles at their base. In some cases the bodies of deep-sea anemones are more rigid and less gelatinous and contractile than those of shallow water forms, and the tentacles are clubbed and arranged in groups. These features, for instance, occur in the *Corallimorphidæ*, which is perhaps, more than any other, an abysmal family, though not exclusively so. The following occur in our area:—(xiv.) *Corallimorphus rigidus*, Moseley, belonging to the family just mentioned, was taken at stations 146, 157 and outside the area at 195. (xv.) *Tealidium cingulatum*, R. Hertw., of the family *Paractidæ*, one specimen taken at station 158, attached to a stone; (xvi.) *Liponema multiporum*, R. Hertw., of the family *Liponemidæ*, taken at station 147, and outside the area at station 305A; (xvii.) *Cereus spinosus*, R. Hertw., of the family *Sagartiidæ*, taken at station 157, and again outside the area at station 237; (xviii.) *Bunodes minuta*, R. Hertw., of the same family, taken at station 147; (xix.) *Sicyonis crassa*, R. Hertw., of the family *Sicyonidæ*, taken at station 147, with a rather cartilaginous, stiff body.

(ii.) Antipatharia. But few species of this sub-order occur at a depth of more than 1000 fathoms, and none of these belong to the large group Antipathinæ. Two species were taken in our area, both at station 145A, from a depth of 310 fathoms, and hardly deserve to

rank as deep-sea forms. They were (xx.) *Schizopathes conferta*, Brook, and (xxi.) *Cladopathes plumosa*, Brook. Both belong to the group Schizopathinæ.

(iii.) MADREPORARIA. The deep-sea Madreporarians are, as a rule, solitary forms, and they present no marked features connected with their abysmal habitat. The following species were taken in our area:—(xxii.) *Flabellum apertum*, Moseley, of the family *TURBINOLIIDÆ*, taken at station 145 in comparatively shallow water, and again off Portugal in 900 fathoms; (xxiii.) *Solenosmilia variabilis*, Duncan, of the family *OCULINIDÆ*, taken at station 145, and off Tristan da Cunha at 1000 fathoms, and again off Ascension Island; (xxiv) *Bathyactis symmetrica*, Moseley, one of the *FUNGIIDÆ*, a form universally distributed in deep-water; it has, moreover, a "wider range in depth than any other animal, occurring in 30 fathoms off Bermuda, and in the East Pacific Ocean at a depth of three miles." It was taken at stations 147 and 157 in our area, and at numerous localities outside; (xxv.) *Leptopenus discus*, Moseley, of the family *EUPSAMMIIDÆ*, taken at stations 147 and 157, and again in the South Atlantic at station 323, is an extraordinary fragile form.

POLYCHÆTA.

Some of the deep-sea Polychæta are phosphorescent, and many have developed large eyes or lost them altogether. There seems with them the same difficulty of extracting lime from the water that occurs in animals of other groups. Many of the Tubicolous forms fail to secrete a calcareous tube, and replace it by a quill-like substance strengthened with sponge-spicules and Foraminifera. These tubes are, in some species, armed with spiny projections.

Of the 220 new species of Polychæta worms brought back by the *Challenger* the following were found in the Antarctic region:—(i.) *Lætmonice producta*, Grube., *APHRODITIDÆ*. This is a very cosmopolitan form, and is known from Iceland and Japan, as well as from many of the stations the *Challenger* explored, where it often was found in considerable numbers. M'Intosh recognises four new varieties of this species. Although, as a rule, a shallow-water genus, this species was found down to a depth of 2900 fathoms. *Polynoë* and *Lagisca* represent the *POLYNOIDÆ*. (ii.) *Polynoë* (*Admetella*) *longipedata*, M'Int., taken at station 146 to the east of Prince Edward Island, is remarkable for the size of its feet and bristles. Only two specimens came up, one of which was a female with large and numerous

ova. This species was obtained nowhere else. (iii.) At the next station (147), near the Crozet Islands, two specimens of *Lagisca crosetensis*, M'Int., were dredged. This species, which in appearance resembles a narrow *Aphrodite*, also occurred at no other station. (iv.) *Nothria abranchiata*, M'Int., *Onuphididæ*, is, as its name implies, remarkable in the genus by having no branchiæ, and, like so many of its deep-sea companions, no eyes. It was dredged both in the Antarctic, station 156, and "in the middle of the Atlantic, north of Tristan da Cunha." It is characteristic of this deep-sea form to have much larger bristles than its congeners. The tubes in which it lived were flexible, coated with a grey mud, Diatom ooze, and strengthened by a long, moniliform, brown, arenaceous Foraminifer. The tubes of the northern form were strengthened by Spatangoid spicules, and the shells of a rare *Dentalium*, of *Aporrhais*, *Bulla* and *Terebratula*, and by one of the valves of a Cirripede. The intestine of the Antarctic form contained the chitinous cuticle of numerous small Crustacea enveloped in Pteropod ooze. Another species of the same genus, founded by M'Intosh on a fragment of the anterior region of the body, is *Nothria armandi*, M'Int., dredged at station 157, about half-way between Kerguelen and Melbourne. It is without eyes. Its tube was friable and composed of Diatoms and Radiolarians. (v.) *Hyalinæcia benthaliana*, M'Int., belongs to the same family, and was taken at the next station (158). One specimen only was dredged, but "what appears to be the same form" was taken a little west of the Northern Island of New Zealand. Its tube is chitinous and semi-transparent. (vi.) At the station 156, and nowhere else, several specimens of *Ephesia antarctica*, M'Int., belonging to the family *Sphærodaridæ*, were dredged. This species is an unusually large and muscular example of the genus. (vii.) *Trophonia wyvillei*, M'Int., representing the *Chlorhæmidæ*, was found at 1950 fathoms, at station 157, an unusually rich spot for Annelids. But a single specimen was dredged. This species is one of the largest and most characteristic of the genus, and is an interesting example of what was at one time regarded as a littoral family. To the morphologist this genus is noteworthy on account of its looped alimentary canal, its single pair of nephridia, and the presence of but two septa.

The family *Maldanidæ* (*Clymenidæ*) is represented by the genera *Maldanella* and *Praxilla*. The *Challenger* first showed that members of this family descended to great depths. "In regard to food, no group shows more strikingly the value of Diatoms, Radiolarians and Foraminifera, as the original food producers for fishes and the higher forms. These groups constitute the chief nourishment of the deep-

sea and many other Annelids, and the majority would seem to live on the spot where they have been swallowed, to judge from their appearance in the alimentary canal of the Annelids.

"The discrimination shown by the family in the formation of their tubes is at once apparent in contrasting the mud swallowed as food with that composing the tube. Almost invariably the latter is coated with the coarser Foraminifera, the larger Radiolaria and the rougher sand particles, and this even in instances where there would have been no obstacle to the admission of the one as well as the other into the buccal orifice." (viii.) *Maldanella antarctica*, M'Int., was taken at three stations, 146, 152 and 157, inside the Antarctic region. Numerous specimens were dredged. With this species, at station 157, was dredged another member of the same family, found nowhere else, (ix.) *Praxilla abyssorum*, M'Int. The species was founded on an imperfect specimen.

The family *Amphictenidæ*, remarkable for the paucity of its examples, was represented in the Antarctic by (x.) *Petta assimilis*, M'Int., taken only at station 147. The genus is interesting because it has a coiled intestine. (xi.) *Amphicteis wyvillei*, M'Int., a single specimen only was dredged at the same station. The alimentary canal of this creature contained *Globigerina* in a fresh condition, showing that Foraminifera inhabit the depths of the sea. It is a member of the family *Ampharetidæ*, which is further represented in Antarctic seas by (xii.) *Grubianella*, a genus described by M'Intosh from *Challenger* material. *G. antarctica*, M'Int., the only species of the genus, was taken at the stations 156, 157 and 158, at depths of 1950–1975 fathoms and 1800 fathoms. M'Intosh recognises one variety.

Of the large family *Terebellidæ*, two genera are recorded, *Leæna* and *Pista*, both represented by a single species founded on a single specimen, which, in the case of the last-named genus, was imperfect. (xiii.) *Leæna antarctica*, M'Int., was dredged at station 156, together with the *Grubianella* and the *Ephesia* of the same specific name. (xiv.) *Pista abyssicola*, M'Int., was taken at station 157.

One or two points of general interest in the deep-sea Polychæta are perhaps worth mentioning here. The types found in what M'Intosh terms the Australian region are "in many cases peculiar and novel." "Comparatively few of the species range into other areas, if we except the ubiquitous varieties of *Lætmonice producta*, and one or two others. Finally, two species of parasitic Crustacea were found on the deep-sea Polychæts; one, *Trophoniphila bradii*, M'Int., adherent to the bases of the branchiæ, with ovisacs project-

ing into the mouth of *Trophonia wyvillei*; the second is *Praxillinicola kröyeri*, M'Int., found on *Praxilla abyssorum*.

MYZOSTOMIDA.

The peculiar parasites grouped under this name are found only on Echinoderms, and, with the exception of one or two recently described cases, they are confined to the Crinoids. There are some seventy species, which are divided into two genera, *Myzostoma*, with all the species but one, and *Stelechopus*, of which there is but one species. Their habit of life varies. Some species crawl freely about their host, others are attached to the ventral surface, and their presence causes more or less marked malformations of the neighbouring parts; others, again, form veritable galls, in which, like an insect in a plant-gall, several individuals pass their life. One species lives in the intestine of its host.

The following were taken in our region:—(i.) *Myzostoma compressum*, von Graff, found on *Bathycrinus aldrichianus*, Wyv. Th., at station 146. (ii.) *M. coronatum*, von Graff, found on the same host at the same station. (iii.) *Stelechopus hyocrini*, von Graff, found on *Hyocrinus bethellianus*, Wyv. Th., and on *B. aldrichianus*, at station 147. It is interesting to note that the ancient form *Hyocrinus* has a special genus of parasite unknown on other Crinoids, though these are abundantly infested with a great number of varied forms. It is also interesting to note that von Graff regards this genus "as undoubtedly the lowest form of the Myzostomida."

GEPHYREA.

The two genera of Unarmed Gephyrea, SIPUNCULOIDEA, which have been found at great depths are *Phascolion* and *Phascolosoma*. Several specimens of (i.) *Phascolosoma pudicum*, Sel., were found round Kerguelen, but at no great depths. (ii.) *Phascolion lutense*, Sel., was, however, brought up in the dredge at stations 156 and 157 from nearly 2000 fathoms. It has a thin, transparent, colourless skin. No specimen of Armed Gephyrean or ECHIUROIDEA was taken in our area, but it is perhaps worth mentioning that *Echiurus chilensis* has been taken in the Straits of Magellan. This genus is the one most common in the colder waters of the globe.

NEMATODA.

Very few Entozoa are known from great depths, though there seems no reason why internal parasites should not flourish as well in

bathybial hosts as in shallow-water forms. A species of Nematode, *Ascaris macruroidei*, v. Linst., has, however, been described "from the stomach of a large Macrurid" taken at station 147, from 1600 fathoms. Another, but a free-living, specimen of the same Class, *Prothelmins profundissima*, von Linst., the type of a new genus and species, was taken at a depth of about 2000 fathoms. This specimen was immature, and is described as a larval form, the largest free-living larva known amongst the Nematoda. It is devoid of any boring apparatus, and is, therefore, possibly free-living throughout life. Wherever the specimen was in the least degree injured the cuticle had rolled up, probably owing to the difference of pressure between the depths and the surface. Its muscular system is peculiar, approximating more to the Gordian worm type than to that of the more typical Nematoda.

Specimens of all animals, especially of fishes, from great depths should, as far as possible, be carefully searched, especially the body cavity and the entire alimentary tract, for Entozoa. It is highly probable that many new forms will in the future be described from this practically unexplored field.

In his monograph on the genus *Serolis*, Mr. Beddard records a species, *S. neæra*, which came up from a depth of 2040 fathoms, but not in our area, and which bore, entangled in its appendages, a number of small Nematodes, apparently free-swimming forms.

Although not an abysmal form, it is worth mentioning in connection with parasites, that a new genus of Tape-worm, *Tetrabothrium auriculatum*, von Linst., was once found in the intestine of a Petrel, *Thalassæca glacialoides*, Smith, in the Antarctic Ocean, and once again in the "Cape Pigeon," *Daption*. A search through the viscera of such birds will almost certainly be rewarded by the discovery of some new forms of Entozoa.

BRACHIOPODA.

The following species are recorded by Davidson from the waters around the Antarctic land or in the neighbouring seas:—(i.) *Terebratula moseleyi*, Dav., west of Kerguelen Island, at a depth of 210 fathoms. (ii.) *T. uva*, Brod., off Heard Island, 10–600 fathoms. (iii.) *T. wyvillei*, Dav., off the Falkland Islands, 1035–2900 fathoms. (iv.) *Terebratulina caput-serpentis*, Linn., west of Kerguelen, 0–1180 fathoms. (v.) *T. murrayi*, Dav., off Kerguelen, 600 fathoms. (vi.) *Waldheimia venosa*, Sol., Tierra del Fuego and Falkland Islands, 5–50 fathoms. (vii.) *W. kerguelenensis*, Dav., off Marion and Kerguelen Islands, 100–150 fathoms. (viii.) *Terebratella dorsata*, Gmel.,

Magellan Straits, 25–90 fathoms. (ix.) *Magasella flexuosa*, King, off Patagonia and in Magellan Straits, 5–15 fathoms. (x.) *Platydia anomioides*, Scacchi, off Marion and Prince Edward Islands, 40–600 fathoms. (xi.) *Rhynchonella nigricans*, Sow., south of Kerguelen Island, 15–150 fathoms.

POLYZOA.

CHEILOSTOMATA.—The following Cheilostomatous Polyzoa were taken from depths of over 1500 fathoms in our region; and the sounding next in depth in the Antarctic was about 200 fathoms:—(i.) *Bicellaria infundibulata*, Busk, taken at stations 147 and 156, belonging to the family *BICELLARIIDÆ*. (ii.) *Bugula bicornis*, Busk, from station 157, belonging to the same family. (iii.) *Bugula reticulata*, Busk, taken at station 147, and, outside the area, at stations 299 and 303. (iv.) *Salicornaria* (*Cellaria*) *magnifica*, Busk, taken at station 157, and, outside the area, at stations 13, 122 and 323, belonging to the family *SALICORNARIIDÆ*, or *CELLARIDÆ*. (v.) *Farciminaria magna*, Busk, taken in the southernmost station, 153, and belonging to the family *FARCIMINARIIDÆ*. (vi.) *Foveolaria orbicularis*, Busk, taken at station 147, belonging to the family *MEMBRANIPORIDÆ*. In this district very many species of Cheilostomata were dredged at a depth of less than 200 fathoms. (vii.) *Onchopora sinclairii*, Busk, of the family *ONCHOPORIDÆ*, was taken at stations 149D, 150 and 157 (at the last-named station in a much damaged condition), from a depth of 1950 fathoms.

CYCLOSTOMATA.—But one species of Cyclostomatous Polyzoa occurred over 150 fathoms in the Antarctic regions. This was (viii.) *Idmonea marionensis*, Busk, taken at stations 147, 151 and, outside the area, at station 320; it belongs to the family *TUBULIPORIDÆ*.

No CTENOSTOMATA or ENTOPROCTA were found in this region.

CRUSTACEA.

Order I.—OSTRACODA.

Conditions at the extreme depths of ocean are unfavourable to the existence of Ostracods, and, as a rule, the "red-clay" and *GLOBIGERINA* ooze of the bottom of the deep sea shows no trace of these minute Crustaceans. Yet they are not entirely absent, and some of them reach a great size. Professor Brady gives a list of fifty-two species, taken in twenty-nine dredgings, at a depth of over 500 fathoms, and of nineteen species, taken in thirteen dredgings, at a

depth of 1500 fathoms downward. In both cases the number of specimens was small, as is the number of species when compared with similar "takes" in shallower waters.

The following were taken, at a depth of 1375 fathoms, between Prince Edward Island and the Crozet Islands:—(i.) *Cythere dasyderma*, Br., station 146, and in many other places, and (ii.) *C. acanthoderma*, Br., at the same station, and elsewhere. These two species appear to be cosmopolitan in all deep seas, but they have not been taken at less depths than 580 fathoms. (iii.) *C. dictyon*, Br., which usually ranges from 1000–2000 fathoms, but has been taken in waters as shallow as 120 fathoms. Taken at stations 146 and 150, and elsewhere. It is a variable species, and seems to be ubiquitous in deep waters. (iv.) *C. viminea*, Br., taken at station 146. (v.) *Krithe producta*, Br., a cosmopolitan and, apparently, a very variable species, taken at station 146, and elsewhere. Many other species were taken in the tow-net and in dredgings down to 150 fathoms in these waters, but the above five represent the deep-sea Antarctic forms.

Order II.—Copepoda.

The only undoubted deep-sea Copepod is *Pontostratiotes abyssicola*, Br., which has been dredged up in the mud from a depth of 2200 fathoms, but not in our area. *Calanus princeps*, Br., *Hemicalanus aculeatus*, Br., *Phyllopus bidentatus*, Br., and a species or two of *Euchæta*, have some claims to be considered abysmal, but none of them have been recorded from the Antarctic region.

Order III.—Cirripedia.

Of the Cirripedes taken by the *Challenger* in Southern latitudes, *Lepas australis*, Darw., was found floating on seaweed near Prince Edward Island. According to Darwin this species is common on *Laminaria* throughout the whole Antarctic Ocean. To this ocean it is confined as far as our knowledge goes. It is, of course, not a deep-sea form, but worth mentioning as peculiar to the Antarctic. (i.) *Scalpellum carinatum*, Hoek, was described from specimens taken near Tristan da Cunha from a rocky bottom some 1000 fathoms deep. No complemental male was found. (ii.) *Sc. africanum*, Hoek. (iii.) *Sc. eximium*, Hoek, and (iv.) *Sc. elongatum*, Hoek, are from the same locality. (v.) *Sc. recurvirostrum*, Hoek, was taken between Heard and Kerguelen Islands at a depth of 150 fathoms. Again no complemental males were found. (vi.) *Sc. brevicarinatum*, Hoek, a typical deep-sea Cirriped, was taken at stations 146 and 147. These

stations were close together. One small complemental male was found. The depth was 1375 fathoms in the one case, and 1600 fathoms in the other. (vii.) *Sc. antarcticum*, Hoek, is the most southern species taken by the *Challenger*, and was represented by a single specimen. It was dredged at station 153 at a depth of 1675 fathoms. Very like it is (viii.) *Sc. tenue*, Hoek, taken at station 146 and at a depth of 1375 fathoms. Complemental males were found in this species. Another new species (ix.), *Sc. flavum*, Hoek, was taken at the same spot.

At station 317, near the Falklands, four specimens of *Verruca gibbosa*, the largest and most beautiful of the deep-sea species, were taken. *Balanus lævis*, Brug., which seems to be peculiar to the Straits of Magellan, was dredged from a muddy bottom some 10–15 fathoms deep. Slightly altered forms, however, creep up the western coast of America. The different individuals adhere together, and form a globular mass. (x.) *B. corolliformis*, Hoek, a very remarkable *Balanus*, with an allied form in the Faröe Channel, was found along with *Sc. recurvirostrum*, and its shell was covered by an encrusting growth of Polyzoa.

Very few, if any, of the Rhizocephalous Cirripeds were brought back by the *Challenger*, but the occurrence of *Peltogaster* is recorded in the naturalists' book.

It has been pointed out that the occurrence of the genera *Scalpellum* and *Verruca* in the great depths of the ocean coincides in a striking way with their palæontological history; but on the other hand there is no instance of specific identity, and the oldest known fossil Cirripede is *Pollicipes*, which is not known from any great depth. It is a widely distributed littoral form, and none of its seven species occur at a greater depth than 10 fathoms.

Order IV.—Leptostraca.

Until the *Challenger* expedition, this extremely interesting order —which occupies an intermediate position between the Entomostraca and the Malacostraca, combining in its members some of the characteristic features of each sub-division—was represented by the single genus *Nebalia*. The *Challenger* added two new genera, *Paranebalia* and *Nebaliopsis*, to the order, each represented by a single species. (i.) *Nebaliopsis, typica*, Sars, was taken, in a fragmentary state, at station 146 between Prince Edward Island and the Crozets. It is again recorded from a depth of 2550 fathoms from station 289, about midway between New Zealand and Chili.

Order V.—Schizopoda.

The Schizopods, though largely pelagic, have many abysmal forms, some of which have lost their eyes, and some are phosphorescent. They are usually of a bright red colour, which contrasts with the pale or transparent appearance of the shallow-water forms. *Lophogaster typicus*, M. Sars, Lophogastridæ, is however, a true bottom form, never found at the surface, and was taken at stations 141 and 142 (just outside our area), but not from depths exceeding 150 fathoms. It is mentioned here as a striking instance of a species found round both Poles, but unknown from intermediate regions, it having been recorded from the Norwegian seas and off the Shetlands, and not again till lat. 34° S. (i.) *Gnathophausia gigas*, Suhm. Part of the moulted skin was taken at station 157, depth 1950 fathoms, and a single specimen, a male, measuring 142 mm., at station 61. This gigantic size, so characteristic of deep-sea Crustacea, is, however, surpassed by the species *G. ingens*, Dohrn; (ii.) *Chalaraspis alata*, Suhm, Lophogastridæ; this species was founded on drawings and notes made by Willemoes-Suhm, the single specimen taken having been lost. The enormous development of the carapace, which covers a good part of the tail, is its most striking peculiarity. It was dredged at station 158. At the same station and at station 146 and many others further north, was dredged (iii.) *Eucopia australis*, Dana, the single genus and species of the family Eucopiidæ. Like many deep-sea forms, its integument is extremely thin and soft, in fact, membranous. The eyes are small and apparently defective. It is a very widely distributed species. Dr. Willemoes-Suhm states that he was "almost sure to get at least a fragment of this Crustacean whenever, in the Mid-Atlantic, true deep-sea mud came up in the dredge or trawl." It is the commonest Schizopod of the deep-sea fauna, and is met with at all depths from 350 to 2500 fathoms. It must at times come to the surface, as Dana's specimen, on which the genus is founded, was taken from the stomach of a penguin shot in the Antarctic. It occurs also in Australian waters and in the Pacific. The great fragility of the skeleton and the softness of the body, render it liable to damage in the dredge or trawl, and fragments are more usually met with than whole animals. (iv.) *Euphausia murrayi*, M. Sars, Euphausiidæ, a large species, 43 mm. long, was taken in the trawl off Kerguelen at no great depth, 96 fathoms, and again at station 154 near the ice barrier. It seems to be confined to the Southern and Antarctic Oceans. (v.) *Bentheuphausia amblyops*, G. O. Sars, as its name

implies, another deep-sea species of the same family, was taken at station 158 and also further north. It seems confined to the abysses of the Antarctic and Southern Seas. (vi.) *Boreomysis scyphops*, G. O. Sars, is a gigantic member of the family *Mysidæ*, measuring 85 mm. in length. Its eyes are very degenerate, without a trace of pigment or "visual elements." It was taken at stations 147, 157, 158, and is known from the Arctic Seas; thus it affords another interesting example of a species which occurs at about the same latitude north and south, but which is unknown from intermediate seas; (vii.) *Amblyops crozetii*, Suhm, belongs to the same family, and as its specific name indicates, it was taken near the Crozets at a considerable depth, 1600 fathoms. To the same family also belongs (viii.) *Pseudomma sarsii*, Suhm, taken at the most southerly dredging, station 153. Other specimens of the species were taken around Kerguelen, but in much shallower water.

Order VI.—Stomatopoda.

This order has no deep-sea species.

Order VII.—Cumacea.

Several species of this order were collected in the neighbourhood of Kerguelen, but none at a greater depth than 150 fathoms. A few deep-sea species are known—e.g. *Leucon tenuirostris*, Sars, and *Eudorella abyssi*, Sars, but not from the Antarctic.

Order VIII.—Decapoda.

The deep-sea Decapoda are, as a rule, characterised by blindness and by a remarkable spininess both of the carapace and of the limbs. The antennæ and limbs are in many cases much elongated, the latter being sometimes as long as four times the body length.

Macrura. Six species of Macrurous Decapods were taken in the Antarctic area. They are as follows:—(i.) *Petalidium foliaceum*, Sp. Bate, belonging to the family *Sergestidæ*, trawled at station 146 near Marion Island, and again at station 159, south of Australia. (ii.) At the former station was also trawled a single specimen of *Glyphocrangon podager*, Sp. Bate, family *Nikidæ*. (iii.) Also at station 146, specimens of *Nematocarcinus proximatus*, Sp. Bate, one of the *Nematocarcinidæ*, a widely-distributed species found again off Valparaiso, in the Arafura Sea, and near Yokohama. (iv.) Another species of the same genus, *N. lanceopes*, Sp. Bate, was trawled at

station 152, the females of which have very large eggs. (v.) *Hymenodora duplex*, Sp. Bate, of the family *Tropiocaridæ*, was taken at station 147, and (vi.) *H. mollicutis*, Sp. Bate, at stations 156 and 157, and in many places further north. Other Macrurous species were dredged in the region, but from shallow depths.

Anomura. Two divisions of Anomura, the Paguridea and the Galatheidea, are true bottom forms, and are numerously represented in the abysses of the ocean. The Paguridea, according to the *Challenger* Report on the Anomura, yield the following four species in our area:—(vii.) *Lithodes murrayi*, Hend., belonging to the family *Lithodidæ*, was taken at station 145A off Marion Island. Depth 85–310 fathoms, bottom volcanic sand. (viii.) *Paralomis aculeatus*, Hend., belongs to the same family, and was taken at the same locality as the preceding. (ix.) *Parapagurus dimorphus*, Studer, belonging to the family *Parapaguridæ*, was dredged at the same time and spot, but only one specimen. This species was also taken further north, living in the shells of *Murex* (*Pseudomurex*) *aëdonius* and *Pleurotoma* (*Mangelia*) *acanthodes*. It has also been found off the Cape of Good Hope in the shells of *Buccinum porcatum*. (x.) *Pagurodes inarmatus*, Hend., of the same family, was taken at station 146, from 1375 fathoms, and again off New Zealand, where it lived in shells of *Pleurotoma* and *Nassa*.

The remaining three species belong to the division Galatheidea and to the family *Galatheidæ* (xi.) *Munida spinosa*, Hend., taken at station 145A, is a strongly spiny form, a common characteristic of deep-sea Crustacea. This species was also taken off Rio de la Plata. (xii.) *Munidopsis subsquamosa*, Hend., taken at station 146, was also dredged west of Patagonia and off Yokohama. (xiii.) *Uroptychus insignis*, Hend., was dredged at station 145A.

Brachyura. The only Brachyurous Decapod peculiar to the Antarctic area, as defined by Dana, is *Halicarcinus planatus* (Fabricius), belonging to the family *Pinnotheridæ*. It occurs very widely throughout the Antarctic, and was taken near Marion Island at a depth of 50–75 fathoms, off Prince Edward Island at a depth of 85–150 fathoms, and in rock-pools at Kerguelen. It extends a good deal further north. It is not a deep-sea form, but is mentioned because it is confined to our area.

Order IX.—Amphipoda.

The number of deep-sea Amphipods is not great. Mr. Stebbing states that there is little doubt the *Lanceola pacifica*, Stebb., was taken at the depth of 2300 fathoms, which was assigned to it by the

naturalists on the *Challenger*. Amphipods occur at a height of 13,300 feet above the level of the sea, at which altitude they have been collected by Mr. Whymper on the South American mountains. The group thus covers a very wide vertical area. Of the thirty-five named species, almost all of them collected by the *Challenger*, which have a more or less doubtful claim to have come from depths exceeding 300 fathoms, five genera represented by as many species, all belonging to the division Gammarini, and all species found for the first time by the *Challenger*, come from the area we are considering. (i.) *Valettia coheres*, Stebb. One specimen only was trawled, and that at station 156. (ii.) *Andania gigantea*, Stebb. Two specimens only were trawled, one at station 146 and one at station 147, both near Marion Island. The specific name refers to the great size of this deep-sea species, which attains a length of some two inches, whereas the earlier known forms averaged $\frac{1}{10}$th to $\frac{1}{5}$th inch in length. (iii.) *Œdiceroides cinderella*, Stebb. Two specimens taken at station 317 near the Falkland Islands. (iv.) *Pleustes abyssorum*, Stebb. One specimen only, taken at station 147 with the *A. gigantea* mentioned just above. (v.) *Atylopsis emarginatus*, Stebb. Dredged at station 145A off Marion Island.

Order X.—Isopoda.

Few groups illustrate so fully as the Isopoda the characteristics of life in abysmal depths. Of the eleven genera peculiar to the deep seas, only two have eyes; of the remaining species, seven have shallow-water representatives with fully-developed eyes. On the other hand it must not be forgotten that some deep-sea forms have well developed eyes, and further, that some littoral forms are blind. Again, the size which is attained by the deep-sea forms in the neighbourhood of both Poles is compared with the meagre proportions of the Isopods of our coasts simply gigantic, *Bathynomus giganteus* reaching a length of nine inches. Corresponding with its great size and with the conditions of its surroundings, this animal has developed special and extensive respiratory organs. *B. giganteus* is further remarkable for having its eyes, which are immense, with some four thousand facets, on the under side of the head, looking downward and not dorsally placed as is usual. *Iolanthe* contains several very large species, and at least two of the genus *Serolis* are gigantic.

A great development of spines is a further characteristic feature of deep-sea Isopods. This peculiarity is recognised by the frequent use of such specific names as *spinosus*, *spinifrons*, *bispinosum*, *quadrispinosum*, etc., and it occurs not only in the deep sea, but in Arctic

and Antarctic species even when they are denizens of shallow water. "Spininess," in fact, seems to be due to the temperature of the water, rather than to the bathymetric distribution. The antennæ are often of enormous length—e.g. *Munnopsis australis*—and may, to some extent, compensate for the loss of eyes.

The following Isopods were taken in the Antarctic seas:—(i.) *Iolanthe acanthonotus*, Bedd., dredged at station 153. This species is represented by a single female specimen that was made the type of a new genus, of which it is the only species. Compared with its nearest allies, it is an extremely long form, and is notable for the immense length of the spiniform, lateral prolongations of its thoracic segments. Eyes are totally absent. It and the next following species belong to the family *Asellidæ*. (ii.) *Ischnosoma bacillus*, Bedd., founded on a fragment, and of the general shape of a *Bacillus*, or stick-insect. It was taken at station 158 at 1800 fathoms, bottom *Globigerina* ooze. The next six species belong to the family *Munnopsidæ*. (iii.) *Munnopsis australis*, Bedd., taken at station 147 and nowhere else. This species again was founded on a single specimen. It was dredged from 1600 fathoms near the Crozet Islands. The body measures some 8 mm. in length, but the antennæ attain the enormous length of 36 mm. The body has a very extraordinary outline. Eyes apparently are absent. (iv.) *Eurycope sarsii*, Bedd. Two specimens were taken at station 146 at 1375 fathoms, and three specimens at station 147 at 1600 fathoms. In all five the limbs were unfortunately broken off. This species possesses peculiar sensory (?) organs on the edge of the maxillipede. (v). *E. fragilis*, Bedd. Numerous specimens were taken at four stations, of which the largest was taken at station 152 at 1260 fathoms. Other smaller specimens were dredged at stations 147 and 152, and again in the Pacific, off the coast of Japan. The species has thus a wider distribution than any other member of the genus, except (vi.) *E. atlantica*, a fragment of which is somewhat doubtful, said to have been dredged at station 147. This fragment also confirms the view that as we approach the South Pole, the size tends to increase. (vii.) *E. spinosa*, Bedd., taken at station 157, and nowhere else, was founded on a fragmentary specimen. It was dredged from a depth of 1950 fathoms, and seems to be a very remarkable form. (viii.) *Acanthocope spinicauda*, Bedd., taken at station 158 at 1800 fathoms. Only one specimen, a male, was dredged. The species is characterised by a long spiniform telson, half as long as the rest of the body. Apparently, during life, it was transparent, as are many members of this family.

Four species of the family *Arcturidae* were dredged in the deep Antarctic sea. (ix.) *Arcturus glacialis*, Bedd., taken at station 153 close to the Antarctic ice-barrier, the southernmost point at which the *Challenger* took soundings. The depth was 1675 fathoms. It agrees with *A. furcatus*, *A. spinosus*, and *A. brunneus* in the extraordinary development of spines upon the carapace and limbs. Only one specimen was taken, and only at the spot mentioned. (x.) *A. furcatus*, Stud. This species has long been known. It occurs in considerable numbers in the shallow waters around Kerguelen and off Heard Island, and it was dredged from 1675 fathoms at station 158, where the bottom is of blue mud. Its occurrence both in deep and shallow water is "most unusual," and worthy of note. (xi.) *A. spinosus*, Bedd. Eight females and three males were taken at a depth of 1375 fathoms at station 146. (xii.) *A. brunneus*, Bedd., of a dark brown, almost black colour. Taken at station 147; two males and two females; a small species, the largest measuring 19 mm.

A special monograph was devoted to the members of the genus *Serolis* collected by the *Challenger*. The following species were taken from the depths in our area:—(xiii.) *Serolis antarctica*, Bedd. This species is blind. It was taken at two stations, 146 and 147, and again in S. latitude 9° 10′. (xiv.) *S. bromleyana*, Suhm, is the giant of the genus, reaching a length in the male of 54 mm. It seems to be a variable species. Specimens were taken at station 156 at 1975 fathoms, from a bottom of Diatom ooze, and from three other stations further north. Many other species of *Serolis* were collected from these waters, but they were not deep-sea forms, and were seldom found deeper than 100 fathoms.

PYCNOGONIDA.

The group Pycnogonida, or, as some prefer to call it, Pantopoda, contains some deep-sea species, but there are no genera of which it can be said they are true deep-sea forms. "As a rule," says Hoek, "the deep-sea species are slender, the legs very long and brittle, and the surface of the body smooth." The following species were dredged in the sub-Antarctic seas:—(i.) *Nymphon hamatum*, Hoek, taken off the Crozets, at stations 146 and 147. It is a fine and beautiful species. (ii.) *N. meridionale*, Hoek. A single specimen of this, the most southerly Pycnogonid described, was taken at station 153. Hoek remarks on the presence of normal eyes in this deep-sea creature. Several other species of *Nymphon* were taken in and around Kerguelen, but at no great depths. (iii.) *Ascorhynchus glaber*, Hoek,

taken at station 146. (iv.) *Colossendeis gigas*, Hoek, a gigantic species, taken at the same time as the preceding, also at station 147, and again further north, in lat. 33° 42′ S. (v.) A more slender species, *C. leptorhynchus*, Hoek, was taken in the same localities as (iv.) (vi). *C. gigas-leptorhynchus*, Hoek, a form intermediate between (iv) and (v.) was taken at station 158. (vii.) *C. gracilis*, Hoek, an eyeless form, though with the oculiferous tubercle persisting, was dredged at stations 146 and 147. (viii.) *Phoxichilidium pilosum*, Hoek, a very hairy Pycnogonid, was taken at stations 147 and 157. It represents the arctic deep-sea forms of the genus. Two other species occur elsewhere at abysmal depths.

Several other species were taken round Kerguelen, but cannot be regarded as deep-sea forms.

MOLLUSCA.

Class I.—Lamellibranchiata.

The bivalves of the deep sea are said by Mr. E. A. Smith to "have a tendency to be without colour, and of thin structure." "The species were apparently few in number in comparison with those of shallow water; and new and peculiar generic forms . . . are of even still rarer occurrence." In this respect both the Lamellibranchs and the Gasteropoda dredged by the *Challenger* proved disappointing.

The following five species of Lamellibranch Mollusca were taken in our area from the depths:—(i.) *Pecten pudicus*, E. A. S., from station 146, of the family Pectinidæ. (ii.) *Amussium meridionale*, E. A. S., of the same family, and taken at the same locality, also at stations 158 and, outside the area, 302. The pigmented ocelli were absent from the mantle edge of this species. (iii.) *Lyonsiella papyracea*, E. A. S., of the family Anatinidæ, was taken at station 157, as were the two remaining species. (iv.) *Silenia sarsii*, E. A. S., an allied form of the same family; also at station 325 at the mouth of the Rio de la Plata. (v.) *Neæra* (*Cuspidaria*) *meridionalis*, E. A. S., an excessively thin-shelled member of the family Cuspidariidæ, was also taken in our area.

Class II.—Gasteropoda.

No Isopleurous Gasteropoda were taken at any very great depths in the Antarctic, the deepest capture being perhaps the Chiton *Lepidopleurus dorsuosus*, Hadd., taken at station 145a, at 310 fathoms.

The ANISOPLEUROUS GASTEROPODA are represented by the following forms:—(i.) *Fusus* (*Neptunea*) *setosus*, Wats., at stations 146 and 147, with a thin, white shell. (ii.) *F.* (*Neptunea*) *calathiscus*, Wats., at station 147, is possibly the same species as the preceding. The genus belongs to the family *FASCIOLARIIDÆ*. (iii.) *Pleurotoma* (*Surcula*) *staminea*, Wats., from stations 146 and 149; and (iv.) *P.* (*Pleurotomella*) *papyracea*, Wats., from station 147, with a shell as thin and delicate as tissue paper, belong to the family *CONIDÆ*. They are so far typical deep-sea forms as to have lost their eyes. (v.) *Guivillea alabastrina*, Wats., formed the type of a new genus of the family *VOLUTIDÆ*. It was taken at station 147, and is described as "a typical *Voluta*." Its eyes, though present, are functionless, since they are destitute of pigment, and the retina, lens and optic nerve are degenerate. This animal is said to be "one of the greatest Molluscan treasures" procured by the *Challenger*. Its shell, some six inches and a half long, is as white as alabaster. (iv.) *Trochus infundibulum*, Wats., of the family *TROCHIDÆ*, taken at station 146, and again at the Bermudas. This animal possesses well developed and apparently functional eyes, which do not differ from those of its littoral congeners. This is an exception to the general rule, that deep-sea Molluscs have no, or very poorly developed, eyes.

On the whole the Antarctic fauna illustrates well the general view that Molluscs from the deep sea are of moderate or smallish size, with thin, delicate and fragile shells. In colour they are inconspicuous, and, as a rule, pale and uninteresting. They are of necessity carnivorous. A large proportion are blind.

Class III.—SCAPHOPODA.

No species was taken inside our area, but just outside, at station 160, *Dentalium leptoskeles*, Wats., was dredged. It shows a deep-sea character in the extreme attenuation of its shell.

Class IV.—CEPHALOPODA.

Three species, belonging to as many genera of Cephalopods, came up with the trawl after a deep sounding in the Antarctic seas. They were:—(i.) *Cirroteuthis magna*, Hoyle, taken at station 146 and, outside the area, at station 298, off Valparaiso, of the family *CIRROTEUTHIDÆ*. (ii.) *Bathyteuthis abyssicola*, Hoyle, taken at station 147, of the family *OMMASTREPHIDÆ*. (iii.) *Eledone rotunda*, Hoyle, from station 157, and again from station 298, outside the area, belongs to the family *OCTOPODIDÆ*.

The first two named belong to families which are regarded as "entirely abysmal," but they possess no striking characteristics associated with a life passed in the abysses of the ocean.

ECHINODERMA.

Class I.—Asteroidea.

Star-fishes are very numerous in the depths. The *Challenger* captured 109 species from a depth of over 500 fathoms, and the number of specimens taken at a single haul was often very large. The Asteroids mentioned below were taken in the sub-Antarctic Ocean at a depth of at least 500 fathoms. Many other species were collected in the same area, but from a lesser depth.

(i.) *Pararchaster pedicifer*, Slad., of the family Archasteridæ, taken at station 147 and again further north at station 143. (ii.) *P. antarcticus*, Slad., taken at the southernmost dredging-station 153. (iii.) *Pontaster forcipatus*, Slad., of the same family, taken at station 146. This is regarded by Sladen as a variety called *echinata* of the species, well known from the deep seas off the N.E. coast of Canada and the United States. It is not known from intermediate regions. (iv.) *Lonchotaster forcipifer*, Slad., also belongs to the family Archasteridæ. It was taken at stations 156 and 157, and is nearly allied to *L. tartareus*, Slad., of the deep water off the West Coast of Africa. (vi.) *Chitonaster cataphractus*, Slad., one of the Pentagonasteridæ, was taken at station 156. (vii.) *Porania antarctica*, Smith, one of the family Gymnasteriidæ, was dredged at stations 145 and 147, and (viii.) *P. spiculata*, Slad., at stations 150 and 151, and again off the Arrou Islands. The genus *Hymenaster*, of the family Pterasteridæ, is represented most fully in the abysms of the sub-Antarctic seas. The following species occur:—(ix.) *H. graniferus*, Slad., a very distinct form, was dredged at station 146; (x.) *H. coccinatus*, Slad., at the same station; (xi.) *H. præcoquis*, Slad., at stations 146 and 147; (xii.) *H. latebrosus*, Slad., at station 157; (xiii.) *H. nobilis*, Wyv. Th., by far the largest species known, was dredged at station 158; (xiv.) *H. formosus*, Slad., at the same station; (xv.) *H. sacculatus*, Slad., at the same station; (xvi.) *H. cœlatus*, Slad., a very handsome species, at the same station; and (xvii.) *H. crucifer*, Slad., at the same station. The family Brisingidæ, peculiarly a deep-sea one, with many species of a uniformly abysmal habit, and often phosphorescent, includes the following three genera:—(xviii.) *Labidiaster annulatus*, Slad., from stations 149, 150 and 151, and again from the neighbourhood of the

Arrou Islands. It seems commoner in the shallower seas than at great depths. (xix.) *Brisinga membranacea*, Slad., a form remarkable for the extremely delicate and rudimentary character of the abactinal skeleton, was taken at stations 146 and 147; and (xx.) *Freyella fragilissima*, Slad., from stations 146 and 156.

Class II.—OPHIUROIDEA.

The following species of Ophiuroids were taken from depths exceeding 1500 fathoms in the Antarctic seas:—(i.) *Ophioglypha loveni*, Lym., belonging to the family *OPHIOLEPIDIDÆ*, at stations 146, 147, 157, 158, 160, an essentially Antarctic form; (ii.) *O. lienosa*, Lym., from station 157; (iii.) *O. fraterna*, Lym., from station 157; (iv.) *O. minuta*, Lym., from stations 146 and 158; (v.) *O. lacazei*, Lym., from stations 160 and (outside the area) 299; (vi.) *Ophiernus vallincola*, Lym., from stations 146 and 156, and outside the area station 76, belongs to the same family; (vii.) *Ophiocten amitinum*, Lym., from stations 146, 152 and 157, belongs to the same family; (viii.) *Ophiocten hastatum*, Lym., from station 146 and (outside the area) 78 and 168; (ix.) *Ophiocten pallidum*, Lym., from stations 156 and 160. (x.) *Ophiomitra sarsii*, Lym., from station 146, belongs to the family *AMPHIURIDÆ*; (xi.) *Ophiacantha cosmica*, Lym., from stations 146, 147, 153, 156, 157, 158, and many others south of the equator, belongs to the same family. The last named species is very widely distributed in the Southern Hemisphere; (xii.) *Ophiolebes scorteus*, Lym., from stations 145 and 147, belongs to the same family; (xiii.) *Amphiura patula*, Lym., from station 156; and (xiv.) *Ophioplinthus medusa*, Lym., from station 156, belongs to the family *OPHIOLEPIDIDÆ*; (xv.) *Ophioplinthus grisea*, Lym., from station 156; (xvi.) *Ophiocymbium cavernosum*, Lym., from station 157. This species belongs to the family *AMPHIURIDÆ*.

Class III.—ECHINOIDEA.

The deep-sea Echinoids have a markedly antique character, especially resembling the fossils of the Cretaceous formations. This feature, which is further emphasised by the Crinoid *Hyocrinus*, a deep-sea form, the only living representative of its genus, has been thoroughly described by Agassiz.

Of the 50 abyssal species, nine (all belonging to allied families) occur in sub-Antarctic waters, and they include the strange *Spatagocystis*, *Echinocrepis* and *Genicopatagus*, all of them characteristic of the Southern seas. These Antarctic species are further peculiar in

that they are found at great distances from large bodies of land. As a rule Echinoids tend to disappear at comparatively short distances from land in other parts of the world.

(i.) *Pourtalesia carinata*, Agass., taken at both station 147 and 157, and also at station 298 further north. (ii.) *P. ceratopyga*, Agass., at station 157, and outside our area at stations 298 and 299. (iii.) *P. hispida*, Agass., at stations 147 and 156. To the same family as the preceding, the POURTALESIIDÆ, belong the next two species. The family, as is not uncommon in abyssal forms, is characterised by the extreme fragility of the test, which renders their preservation difficult. The species also exhibit a high degree of variability, which renders their determination a matter of difficulty and doubt. (iv.) *Spatagocystis challengeri*, Agass., from stations 147 and 157. (v.) *Echinocrepis cuneata*, Agass., two specimens were taken at station 147. (vi.) *Urechinus naresianus*, Agass., of the family ECHINOCORYTHIDÆ, was dredged at stations 146, 147, 158 and again further north at station 302. (vii.) *Cystechinus vesica*, Agass., "the only Spatangoid thus far known which can contract and expand its chest," was taken at the most southern station, 153, as well as further north at stations 298 and 299. (viii.) *C. wyvillii*, Agass., at stations 146, 147, 158, and outside the area at stations 296, 298, 299. This genus also belongs to the family ECHINOCORYTHIDÆ, but the last species, (ix.) *Genicopatagus affinis*, Agass., taken at station 157, is grouped with the family SPATANGIDÆ.

Class IV.—CRINOIDEA.

The deep-sea Crinoids are of extreme interest, inasmuch as many of the forms are stalked, and thus permanently represent a stage passed through in the larval life-history of the unstalked forms, and they also form the modern survivals of what was in past ages a very large group. The fossil stalked Crinoids abounded even in such remote epochs as the Cambrian and Silurian, and their remains bear evidence of the enormous number that once lived. The following five species of unstalked Crinoids, belonging to the family COMATULIDÆ, were taken at deep-sea depths in the sub-Antarctic waters:—(i.) *Antedon abyssorum*, Carp., taken at station 147. (ii.) *A. bispinosa*, Carp., at the same station. (iii.) *A. remota*, at the same station. (iv.) *Promachocrinus abyssorum*, Carp., from stations 147 and 158. (v.) *Thaumatocrinus renovatus*, Carp., a mutilated and probably young specimen, from station 158. Of the stalked forms, (vi.) *Bathycrinus aldrichianus*, Wyv. Th., belongs to an essentially deep-sea genus. It is a member of the family

Bourgueticrinidæ, and was taken at stations 146 and 147 and elsewhere: in fact it seems to be widely distributed in the Atlantic and Southern seas. It occurred in considerable numbers, and this is, indeed, a characteristic of its family. (vii.) *Hyocrinus bethellianus*, Wyv. Th., the sole living representative of the genus, belongs to another essentially abysmal genus and to the family *Hyocrinidæ*. It was taken at station 147, and possibly again near the equator. It thus appears that of the thirteen species of stalked Crinoids known from abysmal depths, but two are recorded from sub-Antarctic seas. A fair number of shallow-sea forms were also taken in this region.

Class V.—Holothurioidea.

This group plays a large part in the Zoology of the deep sea. Here it is not the case of an isolated species or genus adopting the depths of the ocean as its habitat, but a large group, regarded by Théel as a third division equivalent to the Apoda and Pedata (into which, until the date of the *Challenger* investigations, the Holothurioidea were divided), live as true deep-sea forms, and live nowhere else. This group Théel called the Elasipoda. More modern classification places the members of the group in the family *Elpidiidæ*, one of the six which together constitute the Order. The *Elpidiidæ* not only occur in a great number of species which increase in numbers from 50 fathoms down to 2900, but the number of individuals is also large, and they probably form a considerable proportion of the population at great depths. They are very diverse in appearance, and often bizarre in shape, unlike more typical Holothuroids. They tend to lose their radial symmetry, and become flattened, or even concave, ventrally, and rounded above. The body is often produced laterally into a flattened rim, which may have local extensions. Tube feet occur only on the ventral radii, and are often paired, giving the animal an appearance of segmentation.

The following species occurred in the sub-Antarctic area:—(i.) *Psychropotes loveni*, Th., at station 146; (ii.) *P. longicauda*, Th., at stations 156 and 157 in our area, and at station 298 further north. It seems to be a variable species, and attained in one instance the gigantic length of 260 mm. (iii.) *Oneirophanta mutabilis*, Th., at stations 146, 157, 160 and, outside the area at stations 244, 281, 299, 325. A widely distributed and very abundant form. (iv.) *Elpidia purpurea*, Th., one specimen from station 146 and one from station 157. (v.) *E. willemoësi*, Th., one complete and three injured specimens from station 156. (vi.) *E. incerta*, Th., four incomplete

specimens from station 152. (vii.) *E. ambigua*, Th., two injured specimens from station 157. (viii.) *E. glacialis*, Th., station 160. A number of this species are also known from the Kara Sea and the North Atlantic, but in much shallower water. (ix.) *Peniagone affinis*, Th., from station 147, numerous specimens. (x.) *P. horrifer*, Th., a single incomplete specimen from station 157. (xi.) *P. naresi*, Th., one incomplete specimen from station 158. (xii.) *P. challengeri*, Th., two specimens from the same station. (xiii.) *P. atrox*, Th., one damaged example from station 160. (xiv.) *Achlyonice lactea*, Th., four specimens from station 147. (xv.) *Lætmogone wyville-thomsoni*, Th., from stations 147 and 158, and outside the area, from stations 232 and 300. This is a very abundant species. (xvi.) *Scotoplanes murrayi*, Th., one specimen from station 152. (xvii.) *S. insignis*, Th., one specimen from station 156. (xviii.) *S. globosa*, Th., from station 157 and, outside the area, from station 299. (xix.) *S. robusta*, Th., from station 157; only one specimen. (xx.) *S. mollis*, Th., one specimen from station 160. (xxi). *Benthodytes sordida*, Th., from stations 156, 157, 158 and, outside the area, from station 298. (xxii.) *B. sanguinolenta*, Th., from stations 158 and 160, and outside the area, from station 298. (xxiii.) *Scotoanassa diaphana*, Th., from station 160.

Besides the family *Elpidiidæ*, which are essentially and only deep-sea forms, and must have taken up their position in the depths countless ages ago, certain other Holothuroids, belonging to shallow-water forms, have more recently made their way to the depths, but these have, so far, undergone but little structural alteration. They include a very few Antarctic forms:—(xxiv.) *Stichopus challengeri*, Th., of the family *Holothuriidæ*, taken at station 148. (xxv.) *Trochostoma violaceum*, Stud., from Kerguelen, at no great depths. (xxvi.) *Pseudostichopus villosus*, Th., from stations 146, 147, 156, 157, and from numerous localities outside the area. The last two are members of the family *Molpadiidæ*.

TUNICATA.

Ascidiacea.

Ascidiæ Simplices.—The following simple Ascidians were taken within our area:—(i.) *Culeolus recumbens*, Herdm., a species with a small body and a long "peduncle" or stalk, very flexible, like a piece of string, ending in a tangle of filaments which root it to the mud. Test thin and tough, coated with Foraminifera. Calcareous spicules in branchial sac. Taken at station 146. (ii.) *C. perlucidus*, Herdm.,

with a stiffer peduncle, which is quite transparent, and looks like glass: Taken at station 147. (iii.) *Fungulus cinereus*, Herdm., a club-like species, small. Taken at station 147. One specimen only was captured, the type of a new genus and species. (iv.) *Bathyoncus mirabilis*, Herd., from station 147, is founded on a single specimen. This species is allied to *Styela*, but differs in the structure of its branchial sac, in which feature it approaches *Culeolus* and *Fungulus*. (v.) A form *Styela sericata*, Herdm., taken at station 157, resembles a silkworm's cocoon, encrusted with grains of sand, Diatoms, etc. The preceding forms all belong to the family *Cynthiidæ*. Two genera of the family *Ascidiidæ* were found. (vi.) *Corynascidia suhmi*, Herdm., the only stalked member of its family; the body is pyramidal or pear-shaped; the branchial sac is peculiar, and as delicate as a spider's web. It was taken at station 146, and again, outside the area, at station 299. (vii.) *Abyssascidia vasculosa*, Herdm., taken at station 157. The other two families of Simple Ascidians, the *Molgulidæ* and *Clavelinidæ*, are unrepresented in our area. The latter, in fact, are never deep-sea forms.

Ascidiæ Compositæ.—The only genus of Compound Ascidian which extends to a greater depth than 1000 fathoms is *Pharyngodictyon*, belonging to the family *Polyclinidæ*. (viii.) *Pharyngodictyon mirabile*, Herd., is extremely interesting, as, although a compound form, its branchial sac differs from that of all other Compound Ascidians, and exactly resembles that of the deep-sea genera of Simple Ascidians, *Culeolus*, *Fungulus* and *Bathyoncus*. The colony had a curious mushroom-like shape. It was taken at station 147.

The deep-sea Tunicata, as is mentioned above, show very clearly two of the modifications often met with in bathybial forms. One is the development of a stalk, which is well shown in *Culeolus* and *Fungulus*, and to mention a species outside the Tunicata, in the Pennatulid *Umbellula*; and the second is a marked modification of the breathing organs shown both in the Simple and Compound Ascidians and in many deep-sea forms outside the Tunicata.

LIST OF STATIONS IN THE AREA DESCRIBED.

Station 144.—Cape of Good Hope to Marion Island.

Lat. 45° 57′ S., long. 34° 39′ E.
Temp. of water. Surface 43°·0.
Bottom 35°·8.
Depth, 1570 fathoms; deposit, Globigerina Ooze, containing 92·34 per cent. of carbonate of lime.

Station 145, 145A.—Off Marion and Prince Edward Islands.

Off Marion and Prince Edward Islands.

Temp. of water. Surface 41°·5.

Depth, 50–310 fathoms.

Station 146.—Marion Islands to Crozet Islands.

Lat. 46° 46′ S., long. 45° 31′ E.

Temp. of water. Surface 43°·0.
Bottom 35°·6.

Depth, 1375 fathoms; deposit, Globigerina Ooze, containing 86·36 per cent. of carbonate of lime.

Station 147.—Marion Island to Crozet Islands.

Lat. 46° 16′ S., long. 48° 27′ E.

Temp. of water. Surface 41°·0.
Bottom 34°·2.

Depth, 1600 fathoms; deposit, Diatom Ooze, containing 34·63 per cent. of carbonate of lime.

Station 148, 148A.—Off Crozet Islands.

Temp. of water. Surface 41°·0.

Depth, 210–550 fathoms.

Station 149.—Off Kerguelen Island.

Depth, 20–150 fathoms; deposit, Green Mud, containing about 1 per cent. of carbonate of lime.

Station 150.—Between Kerguelen and Heard Islands.

Lat. 52° 4′ S., long. 71° 22′ E.

Temp. of water. Surface 37°·5.
Bottom 35°·2.

Depth, 150 fathoms; deposit, Coarse Gravel, containing about 20 per cent. of carbonate of lime.

Station 151.—Off Heard Island.

Lat. 52° 59′ 30″ S., long. 73° 33′ 30″ E.

Temp. of water. Surface 36°·2.

Depth, 75 fathoms; deposit, Volcanic Sand, containing 2·58 per cent. of carbonate of lime.

Station 152.—Near Antarctic Ice.

Lat. 60° 52′ S., long. 80° 20′ E.

Temp. of water. Surface 34°·5.

Depth, 1260 fathoms; deposit, Diatom Ooze, containing 22·47 per cent. of carbonate of lime, and pebbles of granite and sandstone.

Station 153.—Near Antarctic Ice.

Lat. 65° 42′ S., long. 79° 49′ E.
Temp. of water. Surface 29°·5.
Bottom 33°·0.
Depth, 1675 fathoms; deposit, Blue Mud, containing 3·50 per cent. of carbonate of lime, and many rocks and pebbles.

Station 154.—Near Antarctic Ice.

Lat. 64° 37′ S., long. 85° 49′ E.
Temp. of water. Surface 32°·0.
Bottom 33°·0.
Depth, 1800 fathoms; deposit, Blue Mud, containing 1 per cent. of carbonate of lime.

Station 156.—Near Antarctic Ice.

Lat. 62° 26′ S., long. 95° 44′ E.
Temp. of water. Surface 33°·0.
Bottom 31°·3.
Depth, 1975 fathoms; deposit, Diatom Ooze, containing 2·08 per cent. of carbonate of lime.

Station 157.—Termination Land to Melbourne.

Lat. 53° 55 S., long. 108° 35′ E.
Temp. of water. Surface 37°·2.
Bottom 32°·2.
Depth, 1950 fathoms; deposit, Diatom Ooze, containing 19·29 per cent. of carbonate of lime.

Station 158.—Termination Land to Melbourne.

Lat. 50° 1′ S., long. 123° 4′ E.
Temp. of water. Surface 45°·0.
Bottom 33°·5.
Depth, 1800 fathoms; deposit, Globigerina Ooze, containing 85·31 per cent. of carbonate of lime.

Station 159.—Termination Land to Melbourne.

Lat. 47° 25′ S., long. 130° 22′ E.
Temp. of water. Surface 51°·5.
Bottom 34°·5.
Depth, 2150 fathoms; deposit, Globigerina Ooze, containing 87·90 per cent. of carbonate of lime.

LIST OF STATIONS OUTSIDE THE AREA DESCRIBED,
WITH THEIR POSITIONS.

Station.	Lat.	Long.	Station.	Lat.	Long.
13.	21° 38′ N.	44° 39′ W.	281.	22° 21′ S.	150° 17′ W.
56.	Off the Bermudas.		289.	39° 41′ S.	131° 23′ W.
76.	38° 11′ N.	27° 9′ W.	296.	38° 6′ S.	88° 2′ W.
78.	37° 26′ N.	25° 13′ W.	298.	34° 7′ S.	73° 56′ W.
122.	9° 5′ S.	34° 50′ W.	299.	33° 31′ S.	74° 43′ W.
141.	34° 41′ S.	18° 36′ E.	300.	33° 42′ S.	78° 18′ W.
142.	35° 4′ S.	18° 37′ E.	302.	42° 43′ S.	82° 11′ W.
143.	36° 48′ S.	19° 24′ E.	303.	45° 31′ S.	78° 9′ W.
160.	42° 42′ S.	134° 10′ E.	305A.	47° 47′ S.	74° 47′ W.
168.	40° 28′ S.	177° 43′ E.	317.	48° 37′ S.	55° 17′ W.
195.	4° 21′ S.	129° 7′ E.	318.	42° 32′ S.	56° 29′ W.
232.	35° 11′ N.	139° 28′ E.	320.	37° 17′ S.	53° 52′ W.
237.	34° 37′ N.	140° 32′ E.	323.	35° 39′ S.	50° 47′ W.
244.	35° 22′ N.	169° 53′ E.	325.	36° 44′ S.	46° 16′ W.

XIX.

ZOOLOGY:

KERGUELEN ISLAND: AN INTRODUCTION TO ANTARCTIC ZOOLOGY.

BY PROFESSOR D'ARCY WENTWORTH THOMPSON, C.B.

THE present moment is inopportune for the writing of a fresh account of the fauna of the Southern Ocean. The rich results of the *Valdivia* and *Belgica* remain unpublished, or have been described only in a brief and fragmentary way, and we are accordingly thrown back on older records, and facts that have been more or less familiar to us, knowing all the while that material is already in hand for a great extension of our knowledge. I have confined myself, in the following article, to an account of the Kerguelen area, for which the *Challenger* expedition and the British, American and German Transit of Venus expeditions brought home a copious fauna. This Kerguelen fauna is not strictly speaking an Antarctic, but only a sub-Antarctic one, and such first-fruits as we have of the new knowledge now begin to teach us that the Antarctic Ocean contains other faunistic elements unrepresented in the latitude of Kerguelen; but so little of this new knowledge is yet available that I have perforce confined myself within the aforesaid limits.

Kerguelen forms the lofty crest, and its neighbour, Heard Island, the less elevated spur, of a plateau which rises to a depth of 100 to 150 fathoms out of the deep waters of the ocean; the latter, to the south and west, is about 1500 fathoms deep, somewhat deeper, towards 2000 fathoms, to the eastward, and descends north of the islands of St. Paul and Amsterdam into the still greater depths of the Indian Ocean.*

* The following description of the Kerguelen coast is mainly drawn from Studer's excellent account in 'Die Forschungsreise S.M.S. Gazelle,' part iii. 1889; the zoological account is compiled from Studer, from the *Challenger* Reports, the Reports of the British and American Transit of Venus expeditions, and other sources. A general list of the Antarctic and sub-Antarctic fauna is given by Pfeffer in the 'Ergebnisse der Deutschen Polar-Expeditionen,' Allgem. Theil, Bd. ii. 17. The reader is also referred to Sir John Murray's elaborate paper on the connection between the Antarctic and Arctic faunas in the *Trans. R. Soc. Edin.*

On this island-plateau we have (1) a narrow weather-beaten shore, that is for the most part represented by a basaltic ledge, and only here and there, as at Accessible Bay, expands into a broader beach; (2) a zone of red Florideæ, that occupies the interval between this first ledge and a second which juts out immediately below it at a depth of one to two fathoms; (3) next in order, and four to six fathoms deeper down, is a broader "laminarian" zone, where a forest of Macrocystis grows rooted to basaltic blocks lying loose in mud. These submerged terraces, which are simply the lower members of the basaltic steps that reach to the flat-topped summits of the hills, are smoothed away to a more gradual slope in the various fjords, where a sandy beach passes gradually at about twenty paces from the shore into the black basaltic mud. (4) Lastly, we have the great muddy area of the plateau itself, the mud being intermixed to a very large extent, and more and more as we recede from the island, with the siliceous remains of Diatoms and Hexactinellids.

1. In the first area, the narrow tidal tract presents a poverty-stricken fauna. On the rocks are clusters of small mussels, ascribed by E. A. Smith, Studer and others to *Mytilus edulis*, L., but by Dall to *M. canaliculus*, Hanley. They deserve to be collected in quantity, here and elsewhere; for the Mytili of Chile, the Falklands and New Zealand are all closely allied, and offer, as indeed they do in all other seas, an interesting problem in variation. The soft parts also should be preserved, for in the Southern form they are said by Dall to differ from our Northern one, though this is in turn denied by Smith. Attached to the byssus of these mussels is a minute bivalve described by Dall as *Kidderia minuta*, n. g. et sp., but referred by Smith to Modiolarca, extremely like *Modiolarca pusilla*, Gould, from Tierra del Fuego. Creeping among the rocks is a large Siphonaria, *S. redimiculum*, Rve., closely allied or identical with *S. tristensis*, Leach, from Tristan d'Acunha, and found also in Patagonia and the Falklands. Near low-water mark lives *Trophon albolabratus*, Smith, a form closely allied to *T. philippianus*, Dunker, from the Straits of Magellan, Cape Horn and the Falklands, and still more closely to *T. cinguliferus*, Pffr., from S. Georgia. Next we have a singular little shell identified by Dall with the almost world-wide *Lasæa rubra*, but on the other hand referred by Smith to Kellia, and described, under the name of *K. consanguinea*, as closely akin to *K. miliaris*, Phil., from the Straits of Magellan. Lastly, we have a very interesting and peculiar Chiton, *Hemiarthrum setulosum*, Dall, and a Doris not described in detail, but probably identical with *Archidoris kerguelensis*, Bergh. Within reach of the tide we have also two land-shells, *Hydrobia*

pumilio, Sm., and *H. caliginosa* (Gould). The former is exceedingly minute; the latter was first described from Tierra del Fuego.

It will be seen that the Molluscan fauna of the beach is in the closest possible relation to that of the Cape Horn and Falkland Islands area.

In the clefts of the rocks lives a small pink sea-anemone, the *Bunodes kerguelensis* of Studer, though Andres ('Attinie,' p. 235) is disposed to regard it as a *Sagartia*. Attached to the mussel-shells are colonies of a little Hydroid, *Hydractinia antarctica*, Stud. (whose polymorphism is described as less complete than that of its European ally), and of a larger form, *Coryne* (?) *conferta*, Allm. On the same shells and on stones is a small *Spirorbis*. Of worms we have two peculiar species, *Syllis mytilorum*, Stud., among the mussel-beds, and *Ophryotrocha Claparedi*, Stud., among the green Algæ at low-water mark.

Of Crustacea we have abundantly in the pools, *Sphæroma* (*Exosphæroma*) *gigas*, Leach, with its semiparasitic *Iais pubescens* (Dana), both common also in the Patagonian region and in New Zealand. There are a few Amphipods, *Hyale villosa*, S. J. Smith, *Lysianax* (?) *kidderi*, S. J. Smith, and *Atyloides australis*, Miers, the last-named probably occurring also in Australia. A little red Copepod which has been identified by Brady with the northern *Harpacticus fulvus*, Fischer, but which, perhaps, deserves re-examination, is also abundant.

2. The Floridean zone displays a vastly richer and more beautiful fauna. Here we begin to meet the characteristic Antarctic fishes of the genus Notothenia and its allies, viz. *Chœnichthys rhinoceratus*, Rich., allied to *C. georgianus*, Fisch., discovered by the German expedition in South Georgia; *Harpagifer bispinis*, Rich., common in the Falklands and South Georgia; and some seven species of Notothenia. Of this last genus, whose headquarters appear to be in the Falkland Islands region but which extends to New Zealand and the Aucklands, some species have a range coextensive with the genus, while others are so far only known locally: it is a genus of which new species are certain to be found.

Of Tunicates, there are found in this region: a simple Ascidian, as yet undescribed, similar in size to the northern *A. canina*; and two species of Colella, living attached to the stalks of the Florideæ.

Besides the Mollusca of the shore, we have here among others, *Patella kerguelensis*, Smith, a species akin to the variable *P. aenea*, Martyn, of Patagonia; another Chiton, *C.* (*Acanthochiton*) *castaneus*,

Gould; a very peculiar whelk, *Neobuccinum Eatoni*, Smith; a Natica, *N. sculpta*, v. Martens; and a Photinula, *P. expansa*, Sow., also known from the Crozets, South Georgia and the Falklands, where it is common.

Crustacea are more numerous. The only species of crab found at Kerguelen is the little *Halicarcinus planatus* (Fabr.), which seems to be widely distributed throughout the Antarctic region, though a critical comparison of specimens from different localities is still to be desired. We here meet with the characteristic Isopod genus *Serolis*, represented by two species, one of which, *S. latifrons* (Miers), whose range extends to the Crozets and the Auckland Islands, occurs in great swarms in places where the bottom is sandy; the other species, *S. septemcarinata* (Miers), known also from Marion Island and Prince Edward Island, is less abundant. Many other Isopods also occur, e.g. *Sphæroma gigas*, already alluded to; *Cassidina emarginata*, Guér., a Magellan and Falkland Islands species; *C. maculata*, Stud., possibly not distinct from the preceding (Stebbing, P.Z.S. 1900, p. 561); *Æga semicarinata*, Miers (similar to *Æ. serripes*, M.E., from Péron's voyage); etc.

Bryozoa and Hydroids form numerous colonies on the Algæ and the mussel-shells. A species of Pedicellina, *P. Breusingi*, Studer, deserves further study: it is supposed to be identical with *P. australis*, Ridley, from Magellan (P. Z. S. 1881, p. 61); a Pedicellina, in all probability the same, has also been mentioned by Joliet (C. R. 1879, p. 392) as occurring at St. Paul's Island. Among the Hydroids we have, besides those already mentioned, *Tubularia kerguelensis*, Stud.; *Halecium mutilum*, Allm.; *Hypanthea repens*, Allm.; and two Sertularellæ, viz. *S. unilateralis*, Allm., and another which was at first described by Allman as *S. kerguelensis*, but afterwards referred by him to the widely distributed *S. polyzonias*, L.

A small bright-red Nereis, *N. Eatoni*, M'Int., a *Lumbriconereis* perhaps indentical with the *L. kerguelensis*, Grube, found at greater depths, and a Polynoid, *Hermadion magelhaense*, Kbg., white with reddish-brown elytra, represent our knowledge of the Worms.

Holothurians are abundant, especially *Cucumaria crocea*, Less., an orange-yellow species with brood-pouches for the young; also *Semperia parva*, Ludw., and *Chirodota Studeri*, Théel. *Ophioglypha brevispina*, Smith, is a common brittle-star. Of Asterids we have here the six-rayed *Asterias perrieri*, Smith; also *Porania antarctica*, Smith; and lastly the remarkable *Leptoptychaster kerguelensis*, Smith, whose eggs develop in a cavity on its back, overarched by a roof of modified spines.

3. Leaving the Floridean zone, we come to the zone of Macrocystis, hidden among the roots and borne upon the fronds of which is an abundant associated fauna. A classical passage in the 'Voyage of the *Beagle*' (chap. xi.) records Darwin's vivid impression of this fauna of the kelp, as he saw it in the Straits of Magellan. This kelp fauna deserves careful study, not only for its abundance and comparative accessibility, but also for the interest that would attach to its comparative study at different points along the vast range of distribution of the kelp, from the Antarctic Ocean all along the western coasts of America to Behring Sea.

The thirty-fathom long fronds of Macrocystis are anchored to stones in four to six fathoms of water. On the floating fronds creeps a little white Holothurian, *Pentactella lævigata*, Verr. (also Patagonian), the little *Halicarcinus*, the Isopods already mentioned, and several Limpets, e.g. *Patella kerguelensis*, Smith, *P. fuegensis*, Rve, and especially *P.* (*Nacella*) *mytilina*, Gmel. (the two last being Magellan and Falkland Islands species); also *Admete* (?) *limnæiformis*, Smith, *Littorina setosa*, Smith, *Scissurella supraplicata*, Smith, and others. Bryozoa, especially *Tubulipora organizans*, Busk (as at the Falklands), and *T. stellata*, Busk, also *Lepralia Eatoni*, Busk, *Idmonea marionensis*, Busk (also at Marion Island), etc., cover the fronds, together with the Hydroid colonies of *Campanularia cylindrica*, Allm., and *Hypanthea repens*, Allm. On the roots and stems grow *Diachoris magellanica*, Busk, *Actinopsis rosea*, Studer, and various compound Ascidians, *Amaroucium variabile*, Herdm., *Colella concreta*, Herdm., *Polyclinum pyriforme*, Herdm. Among the tangled roots lives a still richer fauna, of which the following are examples:—*Mytilus magellanicus*, Chemn., numerous Pycnogons, *Nymphon antarcticum*, *N. brevicaudatum*, *Tanystylum styligerum*, all described by Miers; various worms, e.g. *Neottis antarctica*, M'Int., *Nereis eatoni*, *Amphitrite kerguelensis*, M'Int., and a Serpula, said to be identical with *S. narconensis*, Baird; also many star-fish and brittle-stars, e.g. *Amphiura Studeri*, Lym., *Ophioglypha hexactis*, Smith, *Asterias meridionalis*, Perrier, *A. perrieri*, Smith, *Pedicellaster scaber*, Smith, *Pteraster affinis*, Smith (very similar to *P. danæ*, Verrill, said to be from Rio Janeiro), and again the remarkable Luidia-like *Leptoptychaster kerguelensis*, Smith.

Less closely associated with the kelp, but occurring in the same zone, are many other forms, individually numerous, whose dull coloration and, in the case of the Molluscs, ill-calcified shells and thickened epidermis, are in conformity with their muddy habitat and in contrast with the brighter fauna of the Floridean zone. We have

here among the Molluscs, *Neobuccinum eatoni*, E. Sm. (a peculiar genus), the equally remarkable *Struthiolaria mirabilis*, Smith, whose genus has living species in Australia and New Zealand and a fossil one, very similar to *S. mirabilis*, in the Tertiaries of Patagonia, *Natica grisea*, v. Martens, *Rissoa kergueleni*, Smith, and several species of the peculiar little genus Eatoniella, these last on Sponges; also, burrowing in the mud, *Solenella gigantea*, Smith, *Yoldia subæquilateralis*, Smith, and *Anatina elliptica*, King and Brod., which last is known to range as far south as the South Shetlands.

Among Crustacea, the existence of a very interesting fauna is indicated by such examples as *Paratanais dimorphus*, Bedd., and the large and beautiful *Apseudes spectabilis*, Stud. A Nebalia has been found here both by Studer and Willemoes-Suhm; it is said to be indistinguishable from *N. bipes*, Sars.

Of Echinoids we have two species, each of which clusters together in very numerous colonies, viz. *Hemiaster cavernosus*, Phil., and *Goniocidaris canaliculata*, Ag., both also Patagonian. The latter, described by Wyville Thomson as *Cidaris nutrix*, carries its young in "a kind of open tent" formed by the folding inwards of the spines surrounding the mouth, while the former carries them in depressions of the ambulacral areas on its back, protected by the spines. In the last case a singular little Mollusc, *Lepton parasiticum*, Dall, also inhabits the brood-cavity. In equal abundance we have the six-rayed *Ophioglypha hexactis*, Smith, and the seven-rayed *Ophiacantha vivipara*, Lym., both having, in an analogous way, the peculiarity of rearing their young in brood-pouches, and the long-armed *Amphiura Studeri*, Lym. Other species are, *Asterias meridionalis*, Perr., *A. rupicola*, Verrill, *Echinaster spinulifer*, Smith, and *Pentagonaster meridionalis*, Smith.

A single Nemertine, *Lineus corrugatus*, M'Int., is abundant in the mud, where also is one Gephyrean, *Thalassema verrucosum*, Studer. Annelids are numerous, e.g. *Eupolynoe mollis*, M'Int., *Nephthys trissophyllos*, Grube, *Amphitrite kerguelensis*, M'Int., *Neottis antarctica*, M'Int., *Artacama proboscidea*, Mgr., and a curious Chlorhæmid, *Brada mammillata*, Gr., which covers itself with a thick layer of mud, of sponge-spicules and diatom-frustules, all cemented together by the secretions of special glands.

An Anemone, *Edwardsiella kerguelensis*, Stud., is plentiful in the mud, and in somewhat greater depths is another, *Halcampa purpurea*, Studer.

4. With no very sudden demarcation, save for the absence of those species most closely associated with the kelp, we pass to the general fauna of the submarine plateau.

Here we have, in the first place, an abundant fauna of Sponges, as yet very imperfectly known. Foremost among these is the great beautiful Hexactinellid, *Rossella antarctica*, Carter, which is also an inhabitant of the abyssal Indo-Pacific area. Also very abundant is a Tetractinellid, *Tetilla grandis*, Soll. The numerous Monaxonida and Calcarea are chiefly remarkable for the ascription of several of them (in the mean time) to common British or Mediterranean species, e.g. *Halichondria panicea*, Johnst., *Reniera rosea*, Bowerb., *Myxilla plumosa*, Mont., *Suberites carnosus*, Johnst., *Ute capillosa*, Schmidt.

According to Mr. Carter, "Half of the species at the fewest (i.e. of the Transit of Venus collection) may be picked up at any time on the coast of South Devon." Mr. Ridley, however, reporting on the much larger *Challenger* collection, while agreeing with Mr. Carter that the cosmopolitan *Halichondria punicea* of Kerguelen is identical with the British species, and while ascribing one other form, *Stylocordyla stipitata*, var. *globosa*, to a variety of another widely distributed species, considers all his other species distinct and peculiar to the Kerguelen area.

Of the remaining Hydroids we have first the (not too well characterised) Plumularian genus Schizotricha, of which two species are described by Allman; second, a species of Selaginopsis, *S. urceolifera*, Kirch., a genus whose distribution is mainly circum-arctic, with its headquarters apparently in the N. Pacific, and which appears also in Japan and in New Zealand; lastly, two Plumulariæ, one of which, *P. flabellum*, Allm., is recorded also from the Crozets, while the other is ascribed to the common northern *P. frutescens*, Ell. and Sol., and is said to occur also at the Cape of Good Hope.

All the Alcyonaria belong to peculiar species, but one of the three genera, Primnoisis, is as yet only known from this region, the Crozets and Cape Horn. The four species are *Clavularia rosea*, Stud., *Alcyonium antarcticum*, Wrght and Stud., *Primnoisis antarctica*, Stud., *P. ambigua*, Wrght and Stud.

Among the star-fishes, we have in the first place a Brisingid, described by Studer as *Gymnobrisinga sarsi*, though its claim to generic distinction seems not very certain, and also a species of the allied genus *Labidiaster*, *L. annulatus*, Sladen, whose range extends also to the Arafura Sea: the latter genus is known also by another species, *L. radiosus*, Lütken, from the Patagonian region. In the same group the type genus *Brisinga* (*B. membranacea*, Sladen, and *B. discincta*, Sladen) and the nearly allied *Freyella* (*F. fragillissima*, Sladen) are both known from the Southern Ocean. The remarkable genus *Pedicellaster*, sometimes classified with the former genera, is repre-

sented by *P. scaber*, E. Sm. Other species are found at Marion Island and South Georgia, in addition to one West Indian and several North Atlantic forms. *Luidiaster hirsutus*, Studer, is a peculiar form allied to *Pontaster*. *Gnathaster meridionalis*, E. Sm., and *G. elongatus*, Sladen, both occur also at the Crozets, and belong to a small genus known also from the Australian and Magellan regions. One species, indeed, *G. paxillosus* (Gray), is said to occur both at Sandy Point and in the Eastern Archipelago off the coast of North Australia.

The cosmopolitan *Asterias* is represented by *A. studeri*, Bell, *A. triremis*, Sladen, and *A. scalprifera*, Sladen, in addition to the species from shallower water already alluded to; *Solaster*, by *S. subarcuatus*, Sladen; *Cribrella* by *C. simplex*, Sladen. *Perknaster* is a peculiar genus allied to *Cribrella*, of which the two known species, *P. fuscus* and *P. densus*, Sladen, are both from this region. The nearly cosmopolitan *Pteraster* has two species, *P. affinis*, Smith, and *P. rugatus*, Sladen; and the very closely allied *Retaster* has one species, *R. peregrinator*, Sladen, not very different from *R. verrucosus*, Sladen, from the Straits of Magellan; the genus is known from the Cape of Good Hope, the Indian Ocean, and also from the North Atlantic. *Bathybiaster loripes*, Sladen, of the Magellan region, is here represented by its variety *obesa*; the genus has two other species in the North Atlantic.

The cosmopolitan *Gorgonocephalus* has one species, *G. Pourtalesii*, Lym., occurring also at the Crozets and East Patagonia. Of the more typical Ophiurids, many if not most have also been taken at the Crozets, a few, such as *Ophiocten amitinum*, Lym., *Ophiacantha vivipara*, Lym., also in the Patagonian region, and one, *Ophiomyxa vivipara*, Studer, both in the latter region and at the Cape of Good Hope.

Among the Holothurians we have several species of *Psolus*, *P. incertus*, Théel, *P. ephippifer*, Wy. Th., and *P. poriferus*, Studer, all said to be peculiar to the region. The last-named is very briefly described. *P. ephippifer*, Wy. Th., is very like *P. antarcticus*, Phil., from Magellan, and not very different from the northern *P. squamatus*. The cosmopolitan genus *Thyone* has two species and *Cucumaria* two. We have also *Trochostoma violaceum*, Studer, a form not very different from the northern *T. boreale*, M. Sars.

To the Pycnogons already alluded to in connection with the *Macrocystis* zone we may add *Nymphon fuscum*, Hoek (if it be different from *N. gracilipes*, Miers), and two species of *Colossendeis*, *C. megalonyx*, Hoek, and *C. robusta*, Hoek, of which the former is known also from the Patagonian region.

The Amphipods of this region are probably very numerous indeed; the *Challenger* expedition added about fifty species to the half-dozen previously known. Many of the genera, Anonyx, Tryphosa, Hippomedon, Orchomene, Lysianax, etc., are common and widely distributed, and in some cases the species are very similar to their northern allies, e.g. *Hoplonyx cicadoides* (Stebb.), to the northern *H. cicada* (Fabr.) In one instance the Kerguelen specimen is pronounced identical with a northern form, viz. *Podocerus falcatus* (Mont.), but it is suggested as possible that the creature may have been carried southward by the ship; in another such case, viz. *Eusirus longipes*, Bk., Sars holds that the two forms are scarcely identical. But on the other hand the Kerguelen area contains a number of markedly southern genera, of which other species are known either from the Australian or the Patagonian regions, or from both of these, e.g. Acontiostoma, Atyloides, Haplocheira; a considerable number of genera are as yet known only from Kerguelen, e.g. Socarnoides, Cardenio, Acanthechinus, Harpinioides, Zaramilla, Dodecas, Protellopsis; the last three, at least, of these are highly peculiar.

Of the numerous Isopods, one species, *Eurycope fragilis*, F.E.B., is known also from Japan, and with this exception all the rest are confined to the Southern seas. Of the genera, Serolis is highly characteristic of the Patagonian and Antarctic regions; Arcturides, Iolanthe, Astrurus, Neasellus, are all remarkable genera peculiar as yet to the Kerguelen area, while according to Stebbing, the Kerguelen species of Anceus and of Ilyarachna are also sufficiently distinct to deserve the rank of genera. Many of the above genera, and also the species of Apseudes, Tanais, Munna, Pleurogonium and others, are very remarkable, and mark out the Isopod fauna of this region as particularly worthy of close attention.

Of Chætopods, apart from those mentioned above in the description of the shallow-water fauna, we know of somewhat over thirty species, mostly referred to northern or cosmopolitan genera, one genus only, Salvatoria, M'Int., being described as peculiar. Of the species, three are said to be sub-species or varieties of the northern *Lætmonice producta*, Grube, *Scolecolepis cirrata*, Sars, and *Terebellides Stroemii*, Sars. A few others, *Lagisca magellanica*, M'Int., *Eunice magellanica*, M'Int., and three species of Hermadion, are known also from the Patagonian region. *Nereis Kerguelensis*, M'Int., extends to South Georgia; while of the remainder every one is either peculiar to Kerguelen or extends only to the adjacent islands.

Of five species of Brachiopods, two extend to the Patagonian region, *Waldheimia* (*Magellania*) *dilatata*, Lam., and *Terebratella*

dorsata, Gm., and one to the Australian region, *Rhynchonella nigricans*, var. *pyxidata*, Wats.

Of the Mollusca of the deeper waters, besides those already alluded to, we may mention the peculiar and beautiful Volute, *Provocator pulcher*, Wats., and, among the Lamellibranchs, *Davila*, known also only from St. Paul and Amsterdam. The only known cuttlefish is a species of Octopus. The fishes are sufficiently dealt with in the preceding description of the shore.

The foregoing is a very brief epitome of our knowledge of the fauna of the shore and neighbouring waters of a sub-Antarctic island. Already there is material at hand for a great extension of such knowledge when the abundant collections that have been of late brought home shall have been examined and reported on. But, however rich the collections—for instance of the *Valdivia* and *Belgica* —may prove to be, there is yet ample need of further exploration both in the same seas and in the unexplored seas beyond. For, in the first place, it is plain that a comparatively low temperature is no check to the existence of marine life, and that, as in the Arctic seas, so here in the Antarctic and sub-Antarctic regions, we have not a poverty-stricken fauna, but one of great abundance and diversity. And while we can bring no large harvest of new species from any locality whatsoever that is not of value, to fill in for us, as it were, more and more of the scheme of changes and permutations of organic forms, we have furthermore in this case special problems of distribution to solve, for whose solution much more than a superficial knowledge of the Antarctic fauna is likely to be required.

The uninterrupted circle of the Southern circumpolar seas manifestly contains, as it is very natural it should do, a common fauna: many characteristic genera and species are known, and many more will yet be found, to be common to widely distant parts of the region that includes Patagonia, the Falklands, South Georgia, Kerguelen, Australasia, and the islands southward thereof; just as the circum-arctic seas have their common fauna, blended on one side or other with alien elements. Apart from any preconceived theories as to the nature of the Antarctic fauna, it is obviously a fauna of the highest interest in relation to our own, and to the Arctic fauna allied to our own, in order that we may compare the two great marine faunas that exist under similar conditions of temperature while they are widely separated from one another by temperature and depth of sea. A certain superficial resemblance of a negative kind is at once given to these two faunas by the absence of the charac-

teristic fishes, the corals, siphonophores and so forth, that markedly distinguish the tropical seas; on a slightly closer inspection it is equally plain that many prominent genera and larger groups—the genus Serolis, the peculiar Trachinoid fishes for example—are characteristic of the Antarctic and sub-Antarctic waters, and of these alone. But is the residuum only what is common to, or something built upon what is common to, all seas; or does it date back to the conditions of a past epoch, to a fauna that was once common to all seas but is now left only at the extremes of the earth and is obliterated between? It has been maintained by some that this latter is the case; that there is a common bipolar fauna non-existent in the tropics, and even that hundreds of species in the Arctic and Antarctic fauna are identical one with another. This view is contested by others, and I for my part do not share it. But on this question more argument is much less to be desired than more investigation. For, even supposing the specific identity of so many forms to be disproved, it may be that there remains sufficient ground for a similar deduction from the general affinities of the rest: or, on the other hand, if the inference be wholly false, we may find resemblances which are not original, but which throw light on questions of variation and evolution under similar conditions.

We have also minor problems of distribution subordinate to this greater one; for instance, the relation of the common Antarctic fauna to the several faunas of the Atlantic and the Indo-Pacific, and in particular—as has been said above—to that fauna that would seem to go, as the Macrocystis goes, along the comparatively cold shore-waters of Western America to Behring Sea.

While the zoological exploration of the Antarctic needs neither defence nor further recommendation, I cannot help adding, ere I conclude, that I think all British zoologists must be the more anxious that their science should reap a harvest from the forthcoming Expedition, from a feeling that for years past our country has been outstripped in such work by others. Since the pioneer expeditions of the *Porcupine* and their great outcome the *Challenger* expedition, oceanic zoology would have been almost in abeyance with us, had it not been for Dr. Alcock's most productive researches in the Bay of Bengal; while on the other hand, expedition after expedition has been sent out by French and Germans, Americans and Scandinavians. All our experience teaches us that the fauna of the deep sea may be treated as practically inexhaustible for a long time to come. The dredge never comes up without new treasures. The eight hauls made by the *Challenger* in the deep waters of the Kerguelen region furnished

all that we knew, until the other day, of the abyssal fauna of the Southern Ocean. In these eight hauls over 300 new species and about 125 new genera of animals were discovered, and nearly half of these new species were brought up once, and once only; while more recent expeditions, in waters whose fauna is infinitely better known, such as the Danish *Ingolf* expedition in the North Atlantic, the French *Caudan* Expedition in the Gulf of Gascony, and the cruises of the Prince of Monaco, using new and more efficient methods of dredging, and making more minute examination of the material dredged, all show that the proportion of new discoveries tends to increase, and make us regret very deeply indeed that Great Britain has ceased, for over twenty years, to pursue the work of deep-sea zoological investigation.

Lastly, let me reiterate the one request that the naturalist at home makes always of the collector abroad, and that is—to collect everything, even the invisible. After everything that the collector can discriminate has been selected, what remains is likely to be no less valuable. The larger animals, the weeds and zoophytes, the dredge itself, if possible, must be washed, and the washings strained off and preserved; sand and mud must in like manner be carefully stirred and washed, that the contained crustacea and other inhabitants may be sifted out in fine sieves and preserved in bulk; and even the residual sand and mud must not all be simply dried, but must in part be placed in spirits for still closer examination.

XX.

BOTANY.

Compiled by George Murray, F.R.S.

It is very improbable that any flowering plants will be found in the Antarctic regions to be visited by the Expedition, but a careful search, especially for minute forms, should be made. It is needless to say that the discovery of such forms would be of the highest interest; and the following directions (which apply to many of the lower plants as well) are extracted, with modifications, from the British Museum 'Directions for Collecting and Preserving Plants for a Herbarium.'

This is a much simpler process than is generally imagined by those unpractised in it, and travellers have been often deterred from collecting specimens by the time and trouble required for preparing them in the way that has by many been recommended.

The chief circumstances to be attended to are, to preserve specimens of plants in such a manner that the moisture may be quickly absorbed, the colours as much as possible preserved, and such a degree of pressure given to them as that they may not curl up in the act of drying.

For this purpose let a quantity of separate sheets of paper be obtained of a folio size. Common brown paper is upon the whole the best, except for the very delicate kinds, which require paper of a smoother and somewhat absorbent texture. Blotting-paper would absorb the moisture too rapidly, and by repeated damping and drying would soon be rendered useless.

Two boards [or light presses made of galvanised iron wire] should be provided—one for the top and the other for the bottom of the mass of papers.

For pressure when stationary for any length of time in a given spot, nothing serves better than a weight of any kind (a folio book, a large stone, etc.) put upon the topmost board; and the great advantage of this is, that the weight follows the shrinking of the plants beneath.

While travelling, three leathern straps with buckles should be procured; two to bind the boards transversely, and one longitudinally. It will be further desirable to have a number of pieces of pasteboard of the same size as the paper, to separate different portions of the collection, either such as are in different states of dryness, or such as by their bulk might otherwise press upon and injure the more delicate kinds.

Thus provided, gather your specimens, selecting always such as are in flower, and others in a more or less advanced state of fruit.

Place them side by side, but never one upon another, on the same sheet, and lay upon them one, two, or three sheets, according to the thickness of the plants, or their more or less succulent nature: and so on, layer above layer of paper and specimens, subjecting them then to pressure.

As soon as you find that the paper has absorbed a considerable portion of the moisture (which will be according to the more or less succulent nature of the plants and the heat or dryness of the season or climate), remove the plants into fresh papers, and let the old papers be dried for use again, either in the open air or sun, or in a heated room, or before the fire.

As to the spreading out of the leaves and flowers with small weights, penny-pieces, etc., it is quite needless. The leaves and flowers are best displayed by nature in the state in which you gather them, and they will require little or no assistance with the hand, when laid out upon papers, to appear to the best advantage, especially if put in carefully on being fresh gathered.

If the specimens cannot be laid down immediately on being gathered, they should be preserved in a tin box.

In many cases the traveller will find the process accelerated by exposing the parcel (hung up and properly secured) to the open air when the weather is favourable, and the circulation of air through it will be promoted if the sheets on which the specimens are laid be placed alternately back and edge. Four or five shiftings will generally be sufficient to complete the process, which is ascertained by the stiffness of the stems and leaves, and by the specimens not shrinking when removed. They should then be placed between dry papers (such as ordinary newspaper), and formed into parcels of moderate thickness, and either packed in boxes or well secured as parcels covered with oil-cloth.

The greater number of cryptogamic plants may be dried in the common way, such mosses as grow in tufts being separated by the hand. But both mosses and lichens, as they can at any future time

be expanded by damping, may be dried by the traveller without pressure, and put up, either each species separately or several together, in small canvas or paper bags, carefully marking the place of growth and the date when gathered.

With the specimens, fruits and seeds, there should be slips of paper, on which are to be written the colour and form of the flowers, the situation, if dry or damp, the nature of the soil, the elevation above sea-level, and the date when gathered.

ALGÆ.

In collecting sea-weeds, the best kind of receptacle is an ordinary sponge-bag. Glass bottles are dangerous companions between tide-marks, and for the same reason a knife for scraping off specimens should *not* be carried. A stout stick with a chisel end is most convenient, and a cotton bag in a landing-net ring at the other end of it is useful in recovering detached floating specimens. Wading-boots are of great advantage; but where there are deep pools, the risk attending immersion is to be reckoned with. Good specimens from beyond low-water mark are to be obtained after a gale, though many of them are damaged. For dredging, especially from a rowing-boat, Reinke's dredge is the best.

To obtain the microscopic floating plant life of the sea and of fresh-waters (Phyto-plankton) a tow-net of the ordinary pattern, made of No. 20 Miller's silk (to be purchased from Emil Fiechter, 69 Hartington Road, Liverpool), may be used at any depth from a boat or ship going with little more than steerage way. Surface organisms at sea may be got in excellent condition by pumping with the deck-hose through such a tow-net suspended from a boat-davit, or in less abundance by running the bath-tap through a silk bag for a few hours. To those who employ this method, indiarubber hose is to be recommended in preference to canvas or leather hose, on account of impurities discharged from both.

In preparing sea-weed for the herbarium, great care must be taken in spreading each specimen with a small camel's-hair brush on a paper mount inserted below it while floating in a basin. The specimen should then be dried in the ordinary way; but a layer of muslin should be placed over the sheets of specimens to prevent their adhering to the upper sheet of drying paper.

In preserving minute Phyto-plankton, marine Diatoms, and the like, a fluid preparation is best.* Either chromic acid 0·25 per

* The contents in the tail of the tow-net should be emptied into a funnel with a stop-cock, and withdrawn below after settling; failing this, by settling and decanting, or by picking up with a dipping-tube.

cent. solution or platinic chloride 0·5 per cent. solution is excellent as a fixing and preserving fluid; but where minute calcareous organisms are involved, formalin (5 per cent.) gives good results for them as well as for all the other kinds, and is to be recommended for general use.

Special attention in Polar waters should be paid to discoloured water and ice. The former should always be carefully tow-netted; and the latter thawed and filtered. Enormous shoals of marine Diatoms in the Antarctic have been recorded by Sir Joseph Hooker, the *Challenger* expedition, etc., and associated with these, diatomaceous oozes of great extent on the bottom.

Minute fresh-water Algæ are well preserved in carbolic acid (about 1 per cent.), or in camphor water, or weak spirit where these are not to be obtained. Submerged plants should be squeezed, and after the water has stood for some time the upper part may be decanted and the sediment preserved. Scrapings from moist and dripping rocks yield good results.

To the special collector of Diatoms some directions may be given in addition to what has been said above.

Diatoms.

The mud of pools, and of swampy places will repay attention. Where it looks yellow, or shows the presence of Diatoms by giving off little bubbles of gas, it should be scraped up by a fine muslin net attached to a wire frame. The contents of the net should be turned out into a pan, stirred well, and the supernatant sediment poured into a wide-mouthed bottle. Repeat this until there is a good quantity in the bottle, then wash the net and pan thoroughly, and try another place.

In alpine and subalpine places the surfaces of boulders in lakes and streams should be scraped in the same way. These are generally much purer gatherings than the muds. Perpendicular rocks by the sides of streams should be scraped, and the rock faces above the surface of the water should be examined for any little white tufts or patches of Diatoms which have grown there when the waters were higher and have become sun-dried.

The bottles when taken home should be well shaken, the contents poured into filtering-paper, left to dry, and folded up as they are, labelled with locality, approximate height above sea-level, date, and character of the water, whether fresh, brackish, cold or thermal.

Water-weeds, Sphagna, etc., growing in lakes and pools, should be gathered, washed, and gently squeezed in water, and the sediment

treated like the muds. Floating patches of scum which have risen to the surface, buoyed by bubbles of gas on a warm sunny day, should be secured with the net. These are often rich in Diatoms. It must be remembered that small quantities are very difficult to manipulate afterwards.

Marine Diatoms from the surface should be collected by tow-net as described above under "Phyto-plankton."

Ripple markings often exhibit a yellow-brown colour on the sides opposite the sun. This sand should be scraped. and treated in a pan as recommended for the muds. The process should be often repeated, because the proportion of Diatoms to sand grains is often small. Rock pools between tide-marks should be examined, and sloping or horizontal rock surfaces scraped. Algæ in such pools and beyond low-water mark should be treated as noted under "Fresh-water Weeds." Shells, especially living ones, covered with Zoophytes and small Algæ should be scraped, and the scrapings sent as they are. The contents of the stomachs of Holothurians, Ascidians, are often very rich in Diatoms. Dredgings and rubbish from the trawls are often fruitful in diatomaceous remains which have sunk from the surface.

If the surface of peat deposits shows white patches, a slice should be preserved. Any light coloured strata of low specific gravity either under peat or occurring by themselves among other strata deserve attention.

Fungi.

It is probable that minute Agarics and other Fungi will be found, though sparingly.

It is not possible to make satisfactory specimens of soft Fungi such as Agarics in any but a dry climate. Much the best plan is to preserve them in fairly strong spirit, or in formalin diluted with from five to ten parts of water. A note of the colours should be made against the number in the collecting list, or on the ticket; and, if possible, in the case of an Agaric, the colour of the spores should be observed. This is best done by cutting off the pileus, and placing it for several hours on a sheet of paper; and the spores cast during that period will be found to have deposited a map of the gills on the paper. The colour may then be noted; and if possible the spore-cast should be preserved (numbered) by painting a thin film of gum on the *reverse* side of the paper, which should be thin. The pileus should be placed where there is no draught while casting its spores.

Mycetozoa should be dried, and carefully preserved from crushing by fixing them in chip-boxes.

XXI.

ON ARCTIC SLEDGE-TRAVELLING.

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So widespread an interest in the subject of Arctic geographical research has been evinced, that I am encouraged to believe that some details of the means by which that research is chiefly effected may not be uninteresting to those who are here present. And in this belief I have undertaken to give an outline of sledging exploration.

My subject has one feature peculiarly its own—it is this: whereas all other geographical discoveries are performed either by land or by water, modern Arctic exploration into the higher regions of the Frigid zone is prosecuted independently of either, and the ice, which arrests the progress of the ship, forms the highway for the sledge.

In early Arctic voyaging, the ship alone was relied upon for penetrating into unknown seas.

In the second and third voyages of Parry, and the second voyage of Sir John Ross, between 1821 and 1834, sledging was commenced, and a number of short journeys were made, mainly by the assistance of the Esquimaux, whose methods were closely observed and more or less imitated.

But our seamen had not yet familiarised themselves with the idea that it was quite possible for well-equipped Europeans not only to exist, but to travel in an Arctic climate, as well as the Esquimaux themselves; and it was not until the Franklin Searching Expeditions were sent out, between 1848–54, and thus a motive far stronger than that of geographical discovery was supplied, that men seriously reflected upon the possibility of any extensive exploration on foot. And no more powerful incentive could have been imagined to rouse the utmost energies of the searchers, than the protracted absence of the missing Expedition.

The endurance of the hardiest was called forth, and the talent of invention evoked and stimulated, until at length a system of sledging was elaborated, such as I will now proceed to describe.

It may be as well here to explain, that sledge-travelling is limited to the spring months. It cannot be commenced until there is sufficient daylight; it cannot be continued after the summer thaw has denuded the land of snow, or rendered the sea-ice unsafe: therefore it can seldom be prosecuted with advantage before the month of April, or later than June.

The late Admiral Sir James Ross, the distinguished Commander of the Antarctic Expedition, who had served with very great credit in all the six voyages of Parry and John Ross, from 1818 to 1834, formed the connecting link between them and the Searching Expeditions, which commenced in 1848, and the first of which he commanded. He was acquainted with the flat sledges of the Hudson's Bay territory, which alone can be used in deep snow, gliding as they do over its surface; he was also acquainted with the Greenland dog-sledge, with its high narrow runners shod with ivory or bone, and which cut down through the usually thin layer of snow, and run upon the ice beneath; he was familiar with the various modifications of these typical forms, which had been used in the Arctic Expeditions of Parry and John Ross.

He had, moreover, made several journeys with the natives of Boothia Felix, culminating in his discovery of the Magnetic Pole; and, on one of these journeys, he was absent from his ship for the *then* unprecedented period of twenty-nine days.

It was under his directions that our sledges and tents were made in 1848; and these designs, with comparatively slight modifications, have continued in favour in all subsequent expeditions.

The tent requires but little description. It is merely a pent-roof, about seven feet high along the ridge, supported on boarding-pikes or poles, crossed at each end, and covering an oblong space sufficient to enclose the party when lying down, and closely packed together. Its duty is merely to afford shelter from the wind and snow-drift, and its weight, when completely fitted, is, for a party of eight men, only about forty pounds. It is made of light closely-woven duck.

The sledge is a much more important article of equipment. That which our experience has proved to be the most suitable is a large runner-sledge.

It must be borne in mind that I am speaking of latitudes beyond the 70th parallel, where, unlike regions which lie somewhat less remote, the fall of snow is less considerable and never deep; and, moreover, that our sledges often have to be drawn over the sea-ice when flooded with water a foot in depth.

The runners are rather broad, that is, three inches, and they stand

high, carrying the lading about a foot above the ice. An average-sized sledge is three feet wide and ten feet long, and is drawn by seven men. It is constructed with only just so much strength as is absolutely necessary, since every pound of weight saved in wood and iron enables so much more provisions to be carried. All our sledges have been drawn by the seamen, and the labour of doing so is most excessive.

The first sledge expedition in the search for Franklin was led by Sir James Ross in person. By very great efforts a distance out and home of 500 statute miles was accomplished in forty days; but out of the twelve picked men by whom the two sledges were drawn, five were completely knocked up, and every man required a considerable time under medical care to recruit his strength, after this lengthened period of intense labour, constant exposure, and insufficient food.

Throughout this paper the distances will be in English statute miles, as being most generally understood.

It is necessary to apprehend clearly the nature of the surface over which our sledges have to travel.

People unacquainted with the subject commonly fall into one or other extreme, and suppose that we either skate over glassy ice or walk on snow-shoes over snow of any conceivable depth.

Salt-water ice is not so smooth as to be slippery; to skate upon it is very possible, though very fatiguing. But hardly is the sea frozen over, when the snow falls, and remains upon it all the winter. When it first falls the snow is soft, and perhaps a foot or fifteen inches deep; but it is blown about by every wind, until having become like the finest sand, and hardened under a severe temperature, it consolidates into a covering of a few inches in depth, and becomes so compact that the sledge-runner does not sink more than an inch or so: its specific gravity is then about half that of water.

This expanse of snow is rarely smooth: its surface is broken into ridges or furrows by every strong wind. These ridges are the "Sastrugi" of Admiral Wrangell; and although the inequalities are seldom more than a foot high, they add greatly to the labour of travelling, especially when obliged to cross them at right angles.

As the spring season advances the old winter snow becomes softened, fresh snow falls, and sledging is made more laborious still.

At length the thaw arrives; the snow becomes a sludgy mixture, with wet snow on top and water beneath, through which men and sledges sink down to the ice below. It is now almost impossible to get along at all; but in a few days the snow dissolves, and we make fair progress again over the now flooded ice.

Our dry provisions and clothing are so packed upon the sledges as to be protected from the wet, but everyone is of course drenched, and remains so during the march through this ice-cold water. This is cold-water cure in real earnest, but I would not recommend any one with the slightest suspicion of a rheumatic tendency to try it!

Later still the water drains off the sea-ice through cracks or holes decayed in it, and only tortuous pools of water remain upon it.

Later than this, sledge-travelling, without the accompaniment of a boat, becomes unsafe.

Such is the nature of the travelling when the sea-ice has not been crushed up into hummocks, or masses of various sizes and shapes.

We seldom find either unbroken ice, or ice so crushed up into ridges that we cannot get over it at all; but, as a rule, crushed up or hummocky ice, three or four feet in height, is of very frequent occurrence, and, of course, adds much to the labour of sledging.

Having accompanied Sir James Ross on his sledge-journey in 1849, I was entrusted with the preparations for sledge-travelling in the second and third searching expeditions, under Austin and Belcher; and this method of exploration now became recognised as an important feature of these voyages.

The utmost attention was devoted to the travelling equipments, and to the methods adopted by Wrangell and other distinguished Arctic travellers; and the spring parties of the second expedition set out in 1851 on the 15th April, instead of the 15th of May, as in 1849; and the sledges, carrying forty days' provisions, were dragged with less labour than thirty days' rations had previously occasioned: moreover, the allowance was a much more liberal one. The result was a corresponding increase of work done: one party remaining absent for eighty days, and making a journey of 900 miles.

But in 1853 and 1854 the sledge parties of the third searching expedition did still better service: one party accomplished about 1400 miles in 105 days. Another party, having several depôts along its line of route, and favourable circumstances generally, travelled nearly 1350 miles in seventy days.

The two journeys, which have not yet been surpassed, are deserving of our special notice.

The first was purely an exploring journey. Melville Island, which is some fifty miles broad, and is of moderate elevation, had to be crossed and recrossed. At the outset, very heavy loads had to be dragged; and ignorance of the direction in which the unknown coastline might trend, interfered with the deposit of provisions to serve for the return journey; nevertheless, the daily average march was

twelve miles. The second was a despatch journey, and it shows how rapidly ground can be got over with a tolerably light sledge, under somewhat favourable circumstances; and it is a feat which the sailor, who is not generally credited with good marching powers, may justly point to with pride: throughout this journey the daily march averaged the astonishing distance of twenty miles.

These facts afford the strongest proof of the suitability of our travelling equipments.

In any comparisons which we may make between these and any other marches, we should bear in mind that this Arctic work is not merely marching, but that a sledge, often heavily laden, has to be dragged the entire distance.

The provisions and the clothing found to be most suitable may now be briefly described.

Tea, chocolate, biscuit, preserved meat and pemmican are commonly used. Pemmican is a description of preserved meat used by the Indians of North America, from whom it has been copied. It is a preparation of beef, whereby all that is fluid is evaporated over a wood fire; the fibre is then pounded up, and mixed with an equal weight of melted beef fat; no salt or preservative of any kind is used; and no more concentrated food for working-men in a cold climate is known.

With chocolate, biscuit, and a little warmed-up pemmican, the traveller makes a good breakfast; a few ounces of specially prepared bacon, almost free from salt, some biscuit, and a mouthful of grog, forms his hasty luncheon on the march; and, on encamping, he has his supper of warmed pemmican, or other preserved meat, and tea.

Rum is the spirit used in the Navy, and, therefore, in our Arctic ships. If the men were not accustomed to the use of spirits I think that, except on special occasions when a stimulant is desirable, they would be even better without it, as an equal weight of some nutritious food might then be carried instead of it; however, the ration of rum is very small.

This simple dietary is invariable, except when the party is so fortunate as to procure game; and then the awkward question crops up, of fuel wherewith to cook it. We are at a disadvantage with those hardy men who are content to cook their meat with frost; although a sandwich of frozen bear's blubber and biscuit is palatable enough, and I think most of the gentlemen in this room would agree with me if they were fairly educated up to it by a few days' sledging in the month of March.

All our cooking is done with lamps, the fuel being either spirits

of wine, or some fatty substance, such as stearine of cocoa-nut oil, tallow or blubber. The latter alone is used by the Esquimaux; we prefer the stearine, as it cooks more rapidly and makes less smoke, and the stearine lamp suits equally well for blubber, or any animal fat procurable on the march.

The clothing of the men is a subject of equal difficulty and importance; it must be suited to the temperature under which they travel, and this often ranges over 100 degrees, that is, from + 50° to − 50°; it must not suffer by frequent wettings, and should dry quickly; and, as only the outer wrappings of the feet are ever taken off while the frost lasts, it should also be suitable for sleeping in.

Our system of dressing is this: soft, warm woollen articles under a cloth which is impenetrable to the wind, and is commonly known as box-cloth; and this again under a suit of closely-textured duck overalls, as snow repellers.

The feet are wrapped in squares of blanketing, and covered with leather moccasins during extreme cold; or with duck boots, having leather soles, for moderate Arctic cold or for wet.

The entire suit of clothing in wear weighs from sixteen to twenty-one pounds.

The tent furniture consists of a Macintosh floor-cloth spread upon the snow, over which is a thick duffle blanket, and upon this the men lie down in their sleeping-bags, which are made of the same material, and another duffle blanket is then drawn over the party, their knapsacks serving as pillows.

It will be noticed that furs are not used. Although they are very warm and agreeable, when in good condition, to sit in, to sleep in, or even to work in, where they can be dried each night before a fire; and although they have been generally used hitherto, yet they have been deliberately set aside for such dresses as I have described, because we have found that they check the escape of evaporation, they more readily absorb moisture, are more difficult to dry, and shrink much when wetted and frozen. I speak of such furs as are commonly procurable in this country. Those which have been dressed by the Esquimaux or North American Indians are much better suited to our rough work.

Let us imagine the scene when spring travelling-parties set out from their ships to explore the unknown expanse before them.

It was on the morning of the 4th of April that they started from the *Resolute* and *Intrepid*, commanded by the late Admiral Sir Henry Kellett and myself, at Melville Island. Out of the eighty-eight individuals composing the crews of both vessels, seventy-one were away

sledging at one time; each separate sledge party consisting of one officer and six or seven men.

Each sledge hoists a gay silken banner, emblazoned with some heraldic device, some pointed motto, perhaps the name given to the sledge, or perhaps some mysterious initials, known only to the leader of the small party—a little mystery, however, which only awaits the return home of the expedition for its satisfactory solution.

After mutual cheers, they part upon their lonely and toilsome mission. But, trying as is the work before them, it would be difficult to over-rate the enthusiasm displayed. They have just passed through many months of darkness and confinement on board, spent chiefly in preparation for this great spring effort; nor is the keenest emulation wanting to complete a most impressive and characteristic display. Strong sense of duty, and an equally strong determination to accomplish it—dauntless resolution and indomitable will; that useful compound of stubbornness and endurance which is so eminently British, and to which we islanders owe so much—certainly our Colonies and our commerce, possibly even our existence as a nation.

These lonely little parties, daring and enduring so much, resemble sparks from that great fire which, I venture to say, is not yet extinct in this nation—the ardent love of the most adventurous enterprise.

Each officer leads his party, selecting the route, jotting down everything noteworthy in his diary, making a running survey as they advance, and checking his estimated distances by astronomical observations. He is also constantly on the look-out for game. When he can leave these ordinary duties he takes part in the manual labour of dragging the sledge. Clothed and fed like his men, he is housed, or rather tented, exactly as they are, sharing in all things with them; thus he becomes something more than the leader, or even the head of the party: he is its very pulse. These relations fairly established, he receives, in return, the most implicit confidence and devotion of his people. If he reserves anything for his own private use it is his spoon: there being, of course, no washing up of mess traps after meals in frosty weather.

In the extensive sledging operations of the third and last Government Searching Expedition, our entire immunity from severe frost-bites was in strong contrast with the second Expedition, where there were some thirty cases of seriously frost-bitten feet; and this fact affords most satisfactory proof of the greater efficiency of the men's clothing.

Before taking leave of these spring parties, let us glance at them on the march, and notice the amount of work accomplished by those we have already alluded to.

During the month of April the snow is hard, and favourable for travelling, but the winds are, of course, still very cold; and if at all fresh, frost-bites are almost constantly playing about the men's faces. Thirst is also a good deal complained of. May differs in being milder: the sun is now constantly up; snow-blindness is more frequent than frost-bites, and, to avoid it as much as possible, the travellers sleep by day and march by night. Some fresh snow falls, and, therefore, although the sledges are lighter, the labour of dragging is scarcely diminished. Between the old frost-bites, the keen winds and strong sun, all faces are badly blistered; most noses are absolutely raw, and finger-tips quite callous from frequent, though slight, frost-bites. Early in June a few eider ducks, gulls and ptarmigan appear. As the month advances the snow becomes very soft. Soon the thaw bursts forth; the land is rendered impassable by innumerable streamlets; the sea-ice is flooded, and the whole aspect of nature has suddenly changed.

Matters now look serious. But frost-bites are things of the past; even snow-blindness is less troublesome, and the abundance of water is an unspeakable relief. Those who have soap are now tempted to use it! This, however, is the season for rheumatic pains, consequent upon the daily march through ice-cold water. It is well to avoid such late travelling as this.

The travellers return with prodigious appetites; they weigh on an average twelve lbs. less than when they set out; they are reduced in strength as well as in flesh, yet they can walk for hours without fatigue; their sight for distant objects is much more keen, and their powers of observation of external objects, such as traces of men or animals, etc., much sharpened by exercise: in fact, they have advanced a stage towards the condition of the North American Indian.

The nine sledge parties employed in the spring of 1853, from the *Resolute* and *Intrepid*, accomplished in the aggregate 7000 miles, and discovered and explored about 1800 miles of coast-line. This single spring season's travelling may be taken as a suitable basis for calculating what possible amount of work may be performed by the outgoing Arctic Expedition, provided that all the circumstances prove to be somewhat similar.

In the spring operations alluded to Captain Nares took a share, and played his part well, giving proofs of those high qualities which have since borne such good fruit, and which so amply justify his translation from one very interesting and important command to another still more important, more difficult, perhaps the most difficult, to which a commander could aspire.

In the Government Searching Expeditions we gained no experience of snow-houses, and but little of sledging with dogs, yet that little was sufficient to convince us of their value. For instance, during the spring of 1854, our only team of dogs was kept constantly at work, and, without counting occasional short trips, they accomplished in sixty days' travelling, 1830 miles, affording an average rate of thirty miles, their sledge on the whole being rather lightly laden. On several occasions they performed the distance of sixty miles between the *Assistance* and *North Star* in from twenty to twenty-four hours.

The Government having finally abandoned the search, Lady Franklin nobly determined to make one more effort, and in 1857 she sent out the little *Fox*, under my command.

As our entire crew numbered only twenty-four souls, the employment of dogs now became a necessity; accordingly twenty-four were embarked. In the spring of 1859 we sent out from the *Fox* three separate divisions of search, each consisting of six men and six or seven dogs; each division accomplished about 1000 miles of distance, and men and dogs worked harmoniously together for the lengthened period of nearly eighty days.

Dog-driving is so well known that but little need be said here about it. Sometimes there was a little delay at starting, the dogs not allowing themselves to be caught and harnessed. Their harness consists of a few strips of canvas, and a single trace of about twelve feet long, the leading dog having a longer trace than the rest. Once started they are guided by the whip, which the driver should be able to use effectively with either hand. As the dogs on each flank are most exposed to its influence, there is a continual striving to get into the middle, by jumping over each other's backs, so that it is often necessary to halt, pull off one's mitts, and at the risk of frozen fingers, disentangle the traces which have become quite plaited up together. When a dog feels the lash he usually bites his neighbour, who bites the next dog, and a general fight and howling begin. The lash is no longer of any avail, and the driver is compelled to restore order with the handle of his whip. The journey is then more briskly continued for a little time, and so on throughout the march, until at length camping time arrives.

The moment our weary dogs were allowed to cease dragging, they fell asleep and remained motionless, until the cook for the day commenced chopping up the pemmican or the dog's meat. At the first sound of his axe they would spring up and surround him like so many famished wolves, darting upon any splinters of meat which

flew off, or watching an opportunity to steal some pieces. Besides this severe trial of the cook's temper, more of his time was spent in chopping at the dogs than in chopping up the frozen supper. We were careful not to feed the dogs until an hour after halting; when that time arrived, their food (commonly frozen seal's or bear's flesh) was strewed over the snow, and trampled into it, before the *rush* for supper, so as to enable the weak ones to secure an equal share with the strong. I think this was the only care we found it necessary to bestow upon them. We were, of course, obliged to take numberless precautions against them, removing out of their reach anything which they could eat or gnaw.

Dogs are most useful when dispatch is required, or when the temperature is so low that it is undesirable to expose more men than is absolutely necessary. Two men, with a good team of a dozen dogs, can travel with astonishing speed; the men securing themselves each night against frost-bite in a small snow-hut or burrow, when they can find a sufficient depth of snow to do so, but this is by no means always the case on sea-ice at a distance from the land. In this manner I made a journey of twenty-five days, with fifteen dogs, a driver and an interpreter. We started on the 17th of February, and accomplished 420 miles; the temperature, which was sometimes as low as $-48°$, averaged $-30°$ throughout. Snow-huts were built each night, although we were very slow and clumsy masons, requiring an hour and a half, instead of from one-half to three-quarters of an hour to house ourselves! My dog-driver, whose previous experience had taught him what luxuries this mode of travelling was capable of, used to sleep warmly enough, with one dog at his back and another at his feet! An Esquimaux dog is more remarkable for the thicknesss of his fur than for anything else. He has a broad head and chest, keen scent, and strong dislike to the water. Our largest and best dogs measured twenty-three inches high at the shoulders, and weighed about seventy pounds when in fair condition. Two dogs require the same weight of food as one man, and they will draw a man's full load for about one-fourth a greater distance than a man would. If both man and dogs are but lightly laden, the dogs will almost double the distance which the man could do.

I have now completed my brief outline of Arctic sledging operations, down to the return of the *Fox*, the last of the English expeditions.

All the experience gained in that memorable series of voyages between 1818 and 1859 has been brought to bear upon the equip-

ment of the expedition of 1875, and it is further intended that dogs and snow-huts should be used to a considerable extent.

As on former occasions, so now also, upon the persistency of their efforts in sledging will mainly depend the amount of their success.

To sledging we are indebted for almost all our modern Arctic achievements.

To it we confidently look, as a means of escape where neither ships nor boats would avail. And here, permit me to quote from a paper which I wrote some years ago:—

"It is now a comparatively easy matter to start with six or eight men, and six or seven weeks' provisions, and to travel some 600 miles across snowy wastes and frozen seas, from which no sustenance can be obtained. There is now no known position, however remote, that a well-equipped crew could not effect their escape from, by their own unaided efforts."

I had the great satisfaction of learning from Lieutenant Payer, when he recently visited this country, that these words of mine afforded very great encouragement to him and his companions, when their ship became inextricably beset, and when she was finally abandoned in the 80th parallel of latitude.

To sledging we owe many thousand miles of coast-line discovered and explored, and finally, the recovery of the sad, but glorious, record of the heroic deeds of Franklin's Expedition. And to sledging we shall owe the principal share of whatever work may be accomplished by the brave men who have now gone out.

What their measure of success may be, none dare predict.

The public mind, perhaps unaware of the formidable difficulties which surround it, points to the crowning glory of reaching the North Pole—that goal of so much ambition and endeavour.

This consummation is possible, and may the high distinction be theirs. But it is only fair to state, that so little practical improvement could be effected in the equipment of travelling parties, that we cannot reasonably expect that the sledging exploits of 1853 and 1854 will be eclipsed by those of 1875.

However, what has been done will be done again, if the state of the ice is at all similar; but of this we are of course uncertain. This is a grave uncertainty. We know that an open sea has been found at no great distance off the Siberian coast; and that it rendered nugatory all Wrangell's attempts to sledge northwards. Yet it is worthy of remark that Wrangell was one of the first, if not the very first person, to suggest an attempt to reach the Pole from Smith Sound.

No reliable indications of a similar state of things to that which he experienced off Siberia has been found anywhere northward of the islands and shores of America. We have occasionally been startled by announcements of open water; but a little further exploration has proved these iceless spaces, or Polynias, to be very limited in extent, and solely due to local and apparent causes, such as currents or tides, and they have only been found in straits, and not to seaward of an open coast-line.

Captain Nares has this advantage over Wrangell, that he is provided with boats fit to navigate a partially iceless sea, should his sledging be interrupted by water. Now, we know that the failure of Parry's attempt to reach the North Pole in 1827, was largely due to the great weight of his boats, and the consequent difficulty of dragging them over the ice. This error we have attempted to correct, by supplying boats of considerably less than half the weight of Parry's.

But Arctic explorers are well aware that there is one condition which bars all progress: and that is—ice which is too thin to sledge over.

Let us hope that our explorers may not meet with any such insuperable difficulty.

We know full well that ordinary obstructions will but strengthen their determination to solve the great geographical problem committed to them; and we have the satisfaction of knowing that this national undertaking could not be placed in abler hands. They will carry with them the assurance that they have not only our heartiest wishes for their success, but our entire confidence in their resolute endeavours to deserve it.

GEOGRAPHY.

From the "Journal* of a Voyage towards the South Pole on Board the Brig 'Tula,' under the Command of John Biscoe, with the Cutter 'Lively' in Company."

I.

Discovery of Enderby Land.

Nov. 27, 1830.—On the 27th, having completed our water, etc., weighed and made sail to proceed for our southern voyage with the wind northerly. Moderate, but rather hazy. At 4 p.m. the entrance to Berkeley Sound bore west about thirteen miles, when I took sights for the chronometers, and took my departure from lat. 51° 33′, long. 57° 31′ 15″, and the instructions given to me by my owners being, if not inconvenient, to visit the S.E. part of Sandwich Land—and the Aurora Islands having been sought for in vain by Captain Weddell—I thought it advisable to shape a course a few miles to the northward as laid down by the Spaniards, he having made many courses to the southward. On the 28th, our latitude at noon was 51° 57′, longitude by chronometer, 54° 34′ 0″ W. The wind during the night freshened at N.N.W., with thick weather.

Nov. 29.—On the 29th, in the forenoon, passed some patches of kelp. Hazy weather during the whole of these 24 hours. The weather became thick towards midnight, and the wind hauled round gradually to the N.W., and at noon on the 30th blew a heavy gale at W.N.W., when I hauled up E.N.E., to avoid danger to the southward. At 2 p.m. observed the cutter round to, when we took in the foretopsail and foresail, and hove to under balance, reefed mainsail and foretrysail. At 8 p.m. lost sight of the cutter, but on the morning of the 1st December spoke her, and found she had shipped a sea which carried away part of her bulwarks and stove one of her boats. We likewise, unfortunately, on the night of the 30th November lost our jolly-boat from the stern, the hook of one tackle breaking and the bolts drawing off the boat's stern. Moderate breezes from the S.W. with a heavy sea from yesterday's gale. Many albatross and other birds in sight. The observed latitude at noon

* In the possession of the Royal Geographical Society.

was 51° 16′ S., longitude by chronometer, 46° 61′ W., barometer 29° 20′. In the air, 44°. Water, 40°. Light airs from the southward, which towards night came from the S.E., and continued the whole of the 3rd in that quarter with some showers of snow and sleet. In the last four or five days I have found a northerly current of at least thirty miles, the longitude by chronometers and dead reckoning agreeing nearly, and there being that difference betwixt the latitude by dead reckoning and observation.

Dec. 4.—During this day and yesterday the weather has been thick, with the wind from the S.E., and a heavy sea running from that quarter. Many birds, viz. Cape pigeons, stormy and blue petrels, and different species of the albatross about the vessel, and some right whales. On the 6th, a.m., the wind drew round to the northward with fine weather. On the 7th, 10 a.m., observed the distance of the sun and moon, which at noon gave the longitude by means, 34° 43′ 30″, the chronometers 35° 00′ 00″. Latitude 51° 48′ 5″. Light winds from the northward.

Dec. 8.—Thick foggy weather; not thinking it safe to run, hove to; our latitude by account being 53° 21′ S., long. 32° 18′ W., and at 2 P.M., passed close to windward of a small iceberg. On the 9th at noon the weather cleared up for a little time, which allowed me to get an observation, which gave the lat. 52° 46′, by dead reckoning 53′ 18″ S., which makes a northerly set of 32′ in 3 days. Longitude from last observation 31° 12′ W. On the 9th, p.m., the weather continued the same, so that we were continually bearing up and heaving to, as the weather thickened or cleared away. At 2 a.m. on the 10th two large icebergs were observed on the larboard bow, our head being to the northward. At 3, being a little more clear, bore up, passing through a large cluster of icebergs during the day, some very large. As I conceived these to be drifted between Sandwich Land and South Georgia, I kept rather an easterly course, hoping by that means to avoid them. P.M. We had strong gales from the westward. After a short run the weather again became thick; hove to at 10 a.m. Made lights to the cutter, which were answered, but from 11 o'clock saw no more of her, she being then considerably on our weather bow, our head being S.S.W., the wind westerly and blowing a strong gale.

Dec. 11.—A.M. About 1 o'clock found ourselves close down upon an iceberg; wore round to the northward until daylight, when we again stood to the southward in hopes of finding the cutter, as I had given Mr. Avery particular instructions should he part company in a fog, to place himself as near as possible, when it cleared away, in the situation in which he lost sight of us, or if in the night to do the same in the morning, and not under any circumstances to make sail again, or run during the fog, and had he attended to these directions he must certainly have seen us on the 11th at noon, as the *Tula* was never at any time more than five or six miles from the iceberg we saw on the preceding morning. At 12.30 the iceberg bore S. ½ W., and conceiving the cutter might be still further to the westward, I bore up and ran under the lee of it, and

brought it to bear about N.W. distant one mile, when I again hove to, the weather being still hazy, in hopes to see the cutter when it should clear away. At daylight, on the 12th, the weather, more moderate and something clearer than yesterday, continued. Lying to until noon, when not seeing anything of the *Lively*, bore up S.S.E. for Sandwich Land, where I hoped still to find her. What makes it worse than all is that the carpenter is on board her, he having been sent there two days since to repair her boat, and the weather not permitting him to come on board again. I likewise found the barometer broken this morning, but cannot trace out by what means, so must conclude it has burst of itself. Latitude at noon by indifferent observations 45° 7′, chronometers 26° 38′. At 10 o'clock p.m., whilst running under easy sail, the vessel grated over something like coral—though but slightly, as some on deck did not perceive it—which I expect was some floating ice, as we have seen several small pieces lately; but now I could perceive nothing, and although we sounded several times with 100 fathoms of line, found no bottom, and am quite at a loss to conceive what it was. A.M. 13th. Thick weather. Wind W.N.W. 4.30. Hove to, not considering it safe to run, as I find Travers Island laid down at least 6° longitude different in the charts, and likewise much difference in the latitude. At noon, very thick fog. Latitude by dead reckoning, 55° 10′ S. Longitude 26° 15′ W.

Dec. 14.—Strong gales and thick weather as yesterday. For the last eight or ten days I have not been able to get more than two observations which can be depended on. Noon, saw the cutter in the S.S.W.; wore round to close her, spoke her, and found she had not met with any damage. P.M., more moderate. Strong winds from the westward, with snow squalls. Two or three icebergs continually in sight. Very few birds, some stormy petrels, Cape pigeons, and now and then the small albatross with black wings. Saw one sea or Port Egmont hen.

Dec. 16.—Weather fine and more clear. Made all sail to the southward from good sights. The longitude by means of all the chronometers was 23° 30′ 45″; latitude by double altitudes, it being hazy at noon, 57° 00′ S., by dead reckoning 56° 59′ S.

Dec. 17.—The wind veered gradually to the northward and westward, with comparatively smooth water, and although Sandwich Land appears to be imperfectly laid down, I now concluded myself to be under the lee of it. Towards evening it blew a heavy gale of wind from the N.W., with thick weather, which obliged us to heave to, as several icebergs were about us. Some penguins were in sight during the day, with stormy and blue petrels. The snow-birds, or kind of white petrel and some nellies, but no albatross for some days back.

Dec. 18.—Strong breezes, and hazy from north-west by west. Owing to the strong gales from the westward and thick weather, I have been able to make but little progress towards Sandwich Land. Saw two fin-backed whales to-day. Passed several icebergs, and some small pieces of flat ice. Noon, latitude by very indifferent observations, 58° 43′ S.;

longitude by chronometer, 23° 58′ W. Cutter in company, standing to the S.W. with all possible sail. Wind W.N.W. Some thick snows and sleet during the day. Thermometer, air 32°, water 33°.

Dec. 19.—A.M. Many small birds about the vessel, viz. stormy and blue petrels; observed a white gull with its leg broken. Saw also many penguins, some whale and blackfish. Wind strong from the westward, and hazy, so that I could get no observations. Latitude by account at noon, 58° 20′ S.; longitude from last observation of chronometer, 25° 11′ 45″ W; about 8 p.m. saw something on the W.S.W. which had the appearance of land..

Dec. 20.—During the whole of last night and this morning the weather has been so thick we could scarcely see two cables' length from the vessel. Water rather smooth; wind W.N.W., with snow squalls, many penguins and small birds about the vessel.

Dec. 21.—A.M. Heavy squalls with thick snow from the north-westward. Shortened and made sail as the weather required, endeavouring to get to the westward, and at 11.30 a.m. saw land bearing from S. and W. to W.S.W.; wore round to the northward on account of the heavy squalls from the N.W., which brought on thick weather. At noon the latitude by observation (this being the first for some days) was 58° 21′ S.; by account, 58° 17′ S.; longitude by chronometer, 26° 45′ W.; by dead reckoning, 27° 12′. The land on the opposite side to Cape Montagu, bearing about S.W., which has a most terrific appearance, being nothing more than a complete rock of about six or seven miles in length on the east side, and covered with ice and snow, so much so that it was hardly possible to distinguish the rock, the snow and the clouds above these, one from the other, and there being no appearance of a landing place after standing in within five or six miles, it was the opinion of most on board that nothing of consequence could be got, which agreeing with my own ideas on the subject I hauled off to the southward, in hopes to find a better chance elsewhere. The rock, which is quite perpendicular all round to appearance, is laid down at least fifty miles too far east. Many drift pieces of ice about us. Saw a large shoal of blackfish this afternoon, but did not wish to waste time in sending after them. Several icebergs in sight, one of large size appeared to have drifted from the southward, and remained stationary on the southern end of the rock or island we had just left, which by my calculation lies in latitude 58° 25′ S., longitude (*center*) 26° 35′ W. P.M., observed the appearance of land in the S.W.

Dec. 22.—A.M. Hauled to the wind on the larboard tack until daylight, weather being hazy. Wind from west to south. Towards noon it blew a strong breeze from the southward, with clear cold weather. Saw an island to the south-west exactly similar to the first, which bore now W. by N. about twenty-five miles, and not being able to fetch the southernmost, bore away for the other at 4 p.m., being about

four miles from the land. Sent the cutter in with the boats to explore it. The thermometer, while close under the land, was in the air 29°, water 31°. The wind S. by W.

At 8 p.m. the boats returned, not having observed the least trace of seal or elephant, or even been able to find a landing place, as the rock was quite steep to, and no soundings with the hand lead, and nothing to be seen on shore but penguins, which were in great numbers. No birds near the vessel with the exception of some spotted eaglets or Cape pigeons. While lying to for the boats, I observed another island bearing from about N. by W. thirty or forty miles, but as it had the same appearance with the other, i.e. a complete snow bank, I would not lose time in going to it, but filled and stood to the S.E., there being the appearance of land in that quarter. No land in sight. Weather rather hazy. Smooth water, with the wind from S.W. to west. Latitude by observation at noon, 58° 52′ S.; longitude by means of chronometers, 25° 45′ 30″ W.; thermometer, air 30°, water 32°. Passed many large icebergs and drift-ice.

Dec. 24.—At 1 p.m. observed ourselves close down upon field-ice, and much drift-ice about us. Weather hazy. The wind W.S.W.; tacked until it should clear away. At 3 made sail to the S.E., and continued running about a quarter of a mile from the edge of a solid field of ice until 4 p.m., steering various courses to pass through to the southward, but invariably found ourselves in a bay. The water perfectly smooth, with the wind westerly. At 5 p.m. found an opening, and at 6 passed through to the southward into a clear sea. Saw many penguins sitting on the small pieces of ice, which were several times mistaken at a distance for seal. Some blue petrel about us, but no large birds. 8 p.m. several icebergs in sight.

Dec. 25.—At 1 a.m. again made field-ice ahead, but after making a board to the N.W., passed through to the southward, when in a very short time I found we had got into a small sea of seven or eight miles diameter, interspersed with small icebergs and drift-ice, the field-ice making a complete coast as far as the eye could reach. After making various courses, and tacking to pass to the southward and westward in hopes to get through betwixt the ice and the land (as I imagined there must be a little further to the westward), finding it impossible, I got the vessels through to the northward, when we had clear sea until 8 p.m., with the exception of icebergs and some drift pieces, when we again made compact field-ice ahead, which I took to be the same we had been running along on the 23rd, it being evident there were two distinct patches of field-ice, and upon the most moderate calculation we had run through and along one hundred miles of it, being convinced now that there was considerable land to the S.W., and determined, if possible, to make it before going to the eastward. I continued plying to the westward, and not meeting with any field-ice

all night, was in hopes we had got to the westward of it. The thermometer, while among ice, 32° air, 32° water; but after standing some miles to the northward it rose to 34°.

Dec. 26.—A.M., hazy weather. Wind, W.N.W. Found ourselves, on the weather clearing up a little, completely encircled with ice, and had not the water continued smooth our situation would have been extremely dangerous, as, independent of the small seas of field-ice, the whole space was completely covered with drift pieces, some swimming very deep in the water, which a vessel striking upon would most likely knock a hole in her bottom, so that from this until the 29th in the forenoon we were utterly prevented from steering on any one course for more than a few minutes at a time, and every opening which appeared in the ice turned out to be nothing more than a bay, which generally obliged us to haul or beat about again within two or three points of the compass from which we entered, and never at any time had we less than fifty to a hundred ice-islands round us. Where these could all come from I am at a loss entirely to conceive. Whilst among the ice the thermometer generally remained at 32°, the wind generally from the westward.

Dec. 29.—On the morning of the 29th it hauled more to the southward. At 11 a.m. I had the pleasure to find myself clear of the field-ice, with nothing more than the drift pieces and plenty of icebergs, which were thought little of, as the danger seldom appeared to run more than two ships' length from them. At noon our latitude by observation was 59° 11′, longitude by chronometer, 24° 22′ W., and the wind now blowing a fresh gale from the S.W., I determined to spend another day or two in endeavouring to get to Sandwich Land by the northward and westward, and hauled upon the wind on the larboard tack, and at 6 a.m. of the 30th, saw land in the S.W. At noon, two islands of the Sandwich Land bore north and south nearly. The northernmost one I had formerly visited. The latitude at noon was 58° 41′ S., longitude by means of all chronometers 36° 57′ 45″ W., which places the centres in 27° 00′. Latitude of the northernmost 58° 31′ S.—the northernmost part of the southern one 59° 00′ S. Sent the cutter to the northward to overhaul a point of land which appeared to run out low into the sea, and stood to the southward with the *Tula*. At 4 p.m. sent the second mate with the boat on shore. Observed the cutter closing from the northward, sent her boat to some rocks, which appeared likely to produce something. At 9 the boats returned without finding any vestige of seal or elephant, and observing field-ice to stretch from the rocks to the land, the wind easterly, and weather thick, I thought it best to stand to the eastward in prosecution of our voyage.

1831. *Jan.* 1.—Strong winds from the S.E. with thick weather, much snow and sleet. Employed all these 24 hours and the 2nd getting to the eastward.

Jan. 4.—Light airs from the westward. Many penguins about the vessel, and hump and fin-backed whales. No birds, with the exception of the spotted eaglet. Continual showers of snow. Latitude at noon 58° 18′ S., longitude 23° 14′, 30″ W. Variation per amplitude 1° 30′ E., which is the first amplitude I have been able to obtain for a great length of time, and as the observation in general could not be depended upon, I have been unable to form any correct idea with respect to the currents, although I am firmly of opinion that there is a current to the N.E., particularly as I observed one ice-island of large dimensions alter its position with one of the islands of Sandwich Land at least 10 miles within 24 hours, in the direction with the wind at W.N.W., which should have set it to the E.S.E., and although the vessel did not experience any current on the surface it must have been very strong underneath. On the morning of the 5th we again made field-ice. The water smooth and the wind being from the eastward, were obliged to tack; we again stood in, working along the edge of it, and found it quite firm. Latitude at noon, 59° 8′ S., longitude by means of chronometers 21° 30′ W. P.M., the wind hauled more to the northward, which enabled us to steer along the edge, endeavouring to pass to the southward, and were always obliged to haul out again, every extremity being nothing more than the point of a bay. I observe by Captain Cook's track to the eastward, that he passed along in about 58° 45′ S., and I think it very probable he was prevented from getting to the southward by this ice.

Jan. 6.—Light variable weather, but the wind generally from the southward. Firm field-ice to the southward, and considerable loose floating pieces about us. Passed many very large ice-islands, some of most extraordinary shape.

Jan. 7.—On the 7th the wind freshened from the S.S.W., and brought clear weather. At 8 a.m. passed to the southward of a large patch of field-ice, which appeared to be connected together by several large icebergs. No field-ice in sight to the southward. No birds or penguins in sight. Latitude at noon, 59° 35′ S., longitude, chronometers, 19° 52′ W. Thermometer, 32° air, water 32°. I was now in great hopes I had got to the southward of the main body of the ice, but this delusion soon vanished; for at 10.30 p.m. we again made field-ice ahead, being then on a wind, and heading S. by E. ½ E., and had now run upwards of 40 miles S.S.E. since noon, and had seen nothing but icebergs. I immediately hove about, and after making two or three tacks the ice became very close, leaving us scarcely working room, but as the night was clear and the water smooth, I was still in hopes of working through this packed ice to the southward into clear water: but at 2 a.m. of the 8th all my hopes were destroyed, for suddenly I found myself at the head of a bay of firm ice, with a view of it from the mast-head of at least 20 miles to the southward of east and west in every direction, so much so, that any person might have walked upon it without difficulty.

The weather being now so very clear, I am convinced land might have been seen at 80 or 90 miles distance, although during the evening several appearances of land had been observed. What astonished me most was that there were no living animals of any kind about this ice with the exception of one or two small petrels—no penguins, which at other times had been always very numerous, which almost convinced me that this ice must be formed at sea from the very heavy falls of snow which here are almost continual. The temperature of the water at this time being below freezing 2°, and the whole of the ice above water having the appearance of snow, makes it, I think, probable. Temperature, air 31°. The head of the bay was so small, that in veering to return we ran round nearly the whole of it, but could observe no opening whatever. I now found almost as much difficulty in returning as before in entering, for although the wind was fair, still the whole space appeared one complete mass of unbroken ice; but at 5 a.m. succeeded in getting into tolerably clear water, and steered a course to pass to the eastward of the patch we had left yesterday at noon. At 8, hauled up east, but again made compact ice, and after steering various courses along it, found that at noon we had made a N.E. course of about 12 miles from yesterday; our latitude at noon being 59° 27′ S., we continued working along the edge of the ice until 1 a.m. of the 9th. At noon our latitude was 58° 31′ S., and longitude, by means of all chronometers, 17° 06′ 00″ W. During the morning of the 10th we again had to make various courses to clear the ice, and at noon had made from yesterday a northerly course of 58°. It came on to blow strong from the southward, and at 4 p.m. blew a heavy gale, which lasted until 8 a.m. of the 11th. During the gale I steered an easterly course, but was much surprised to find a very heavy sea running, although we could not be more than 35 miles to the northward of the ice. Passed three ice-islands in the night. At noon, hauled up S.E., the weather being more moderate, and wind about W.S.W., but at about noon of the 12th found we had made little better than an E.S.E. course, which at the time I attributed to a strong northerly current, but since find it must be owing to the sudden increase of westerly variation.

Jan. 13.—On the 13th and 14th the wind was very light and variable, but generally more from the southward than any other point, with intervals of calm, and so very thick that on the night of the 13th we could not see the cutter twice our length, although hailing and speaking to her at different times, and at last made a line fast to her to prevent our separation. At noon on 14th, on clearing up, found ourselves close to some heavy patches of ice with 32 icebergs about us. Latitude 58° 57′ S., longitude, chronometers, 9° 47′ 20″ W.

Jan. 15.—A.M. Passed through a slack place on the ice and stood to the southward, endeavouring to pass through, but after running some miles into it found it nothing but a bay, and were obliged to haul

out again to the northward. At noon, latitude 59° 13′ S., longitude 7° 50′ W. During all this night and the 16th the wind, with the exception of intervals of calm, was from the S.W. with very fine weather.

Jan. 16.—We were employed coasting along the ice, and at noon had made an E. course 50 miles, with 58 icebergs in sight. Thermometer in the air 45°, water 34°, but in the sun it immediately rose to 77°; in fact it appeared more like a summer in England than what I had expected in these latitudes, and since the first day of making Sandwich Land we had had but two strong winds, both of which were from the S.W. The weather has been repeatedly thick, but in other respects remarkably fine, and the winds light. On coming into these latitudes I had sent down the foretopgallant-yard and mast, studding-sail booms, &c., but have since found it absolutely necessary to send them up again.

Jan 17.—At noon we had made a southerly course of 60°, being now in latitude 60° 12′, longitude, chronometers, 7° 00′ 00″ W. No field-ice in sight, and very few icebergs, variation by amplitude 11° 30′ W., thermometer, air 44°, water 36°, in the sun 60°. The wind light from S.W., and continued so from the southward and S.W. until the forenoon of the 18th, when it became fresh and steady from S.W., but brought but little sea up. The difference between the latitude by account and observation was 11 miles, which I think must arise from the great increase of variation west, judging from the last amplitudes. We have nearly a clear sea, only six or seven icebergs in sight from the mast-head, and in all probability have got to the southward of the main body of the ice. Our latitude at noon, 61° 2′, longitude 4° 36′ W.; thermometer, air 35°, water 33°. Some showers of snow. Only a few small petrels in sight.

Jan. 19.—Steady and fresh breezes from the W.S.W., but during the night hauled round to the northward, and from that to E.N.E. and east, and blew fresh all the 20th. At noon our latitude was 64° 34′ S., longitude by chronometers 00° 15′ 15″ W., variation, computed from the courses 15° W., a northerly set of 26′ during the last three days. We are continually passing ice-islands, some very large, with drift pieces of ice, but have never more than ten or fifteen in sight at one time. I should think we pass 150 every 24 hours. Scarcely any birds to be seen. Yesterday we saw 2 nellies and one albatross, being the first since leaving the latitude of South Georgia. The mornings and evenings are in general very cloudy. No amplitudes, nor have I been able to get a lunar for a great length of time. During the latter part of the night the wind came round to the S.E. At 8 a.m. we had only 1 ice-island in sight.

Jan. 21.—A.M. One ice-island in sight. Saw a nelly and two or three spotted eaglets with some blue petrel. Noon, latitude 66° 16′, longitude

00° 24′ 30″ W., thermometer, 38° air, 36° water. No ice of any description in sight. The wind moderate from the S.E., with occasional snow squalls, and many appearances of land at different times, which hitherto have turned out to be fogbanks. P.M., saw the appearance of land. Tacked to the southward and westward. Wind variable, but inclining to the southward. Sunset, nothing in sight, tacked to the eastward; saw this day a new description of bird of the eaglet kind, about the size of a Cape pigeon, or rather larger, with brown back, wings and head, the other parts of the body white.

Jan. 22.—Variable, with smooth water. Latitude by account, 66° 48′, longitude, 1° 02′ 30″ E.; variation per amplitude, 22° 30′ W. Passed one iceberg during the night. Temperature, air 33½°, water 35°, midnight 34½°.

Jan. 23.—A.M. Cloudy weather overhead, but much lighter nearer the horizon. The wind generally from S.S.W., but suddenly dying away and springing up as the land or some other object obstructed it. The water smooth and at times discoloured; some brown eaglets and Cape pigeons about the vessels. At noon our latitude by observation, 67° 42′ S., longitude by chronometer, 3° 31′ 36″ E. Temperature, air 31°, midnight 31°; water 35°. Wind more steady at S.W., with clear weather and a clear sea. P.M., passed several icebergs, and towards night the wind increased to a strong gale at S.W. by S., and continued until 8 a.m. of the 24th, when it moderated. Several islands of ice in sight. Temperature, air 33°, midnight 32°; water 34½°. P.M., passed through some straggling ice. At 4, saw field-ice running to the southward and westward to a great distance. At 6, passed the apparent point of the ice, our head being E.S.E., with the wind S., with snow squalls and hazy weather.

Jan. 25.—A.M. The wind hauled more to the eastward, with thick weather. Tacked to the southward. At noon, latitude by observation, 67° 57′ S., longitude, chronometer, 8° 28′ 45″, variation 21° 30′ W. P.M., wind E.S.E. Made much straggling ice ahead, and passed through a great many patches, but the weather becoming more thick, with frequent snow squalls, and the ice more compact. Tacked to the northward until 7.30, when, having pretty clear water, stood again to the southward, with the wind at E. and E. by N. Hazy weather with snow at 9, many patches of ice ahead. All this night, and the forenoon of the 26th, we were employed working along the edge of broken fields of ice. Passed much loose ice and many icebergs. At noon it blew a brisk gale from the eastward and S.E., with a heavy sea and thick weather. Stood S.S.E. until 6 p.m., when the weather still continuing thick, and having entered again into the loose ice with many icebergs about us, some of which we could not see until within a cable's length, tacked to the northward. At noon, the 27th, the weather became more clear. The wind E.S.E. to S.E., with an ugly sea, and as there has never been much

sea when in or near the ice before, I am inclined to think there is not much to the S.E. Accordingly we stood to the southward, our latitude 68° 01′ S., longitude, 10° 7′ E.; temperature, air 31°, water 34°. Much snow the last two days. Saw some penguins seated on the icebergs, but very few birds, one nelly this morning.

Jan. 28.—On the 28th, a.m., again made field-ice; much broken. Passed through a great quantity of loose ice, tacking every two or three hours, endeavouring to get to the southward. The wind continuing from E.S.E. to S E. with sudden squalls of snow and thick weather. The sea smoother than yesterday. At 6 p.m., while standing to the southward, we suddenly, on the weather clearing up, found ourselves completely beset with large pieces of drift-ice. The helm was immediately put down, and by the careful management of the sails we were enabled to pass through two large pieces of about the size of our hull, which showed themselves under the bows, just as the head-yards were hauled, the vacancy between just sufficient to admit the vessel through, the cutter being a short distance astern avoided the danger. The whole of this day and the 29th we have been employed working along these broken fields of ice, and consequently have made but little progress. Temperature, air, at noon, 30°, water 30°. Latitude by account from L.O. 69° 03′, longitude, L.O. 10° 43′ E. Many snow birds and brown eaglets in sight. The second mate saw an albatross yesterday.

Jan. 30.—On the 30th the wind continued from the E.S.E., with little variation. Passed through a considerable quantity of broken ice, and both vessels took some on board for present use, and, contrary to my expectation, I found much of it salt. At midnight the weather became so thick that, although I could speak the cutter I could not see her, and as we were now completely surrounded by broken ice and obliged to use the sweeps, I made a line fast to her to prevent our separation, the weather quite calm and sea smooth. I observed the surface of the water in a freezing state, having a film over it connecting one piece of ice to another, but their motion seemed to prevent its getting into a firm state; but I have no doubt, had it been the winter season, and the same length of calm, the sea would have been frozen. I am almost of opinion the greater part of this ice is formed at sea, and that field-ice is no certain indication of the proximity of land. I found the temperature of the air 26°, in the shade 27½°, water 29°. I think ice formed in this way may be rendered fresh by the continual falls of snow, which may freeze as it falls and repel the influence of the salt water, except on its outer surfaces.

Jan. 31.—Towards noon the weather, though still very hazy, became less foggy, and a light breeze sprung up from the eastward and continued light from the E.S.E.

Feb. 1.—A.M. Mr. Avery reported having seen a seal near the cutter, and as we had now many snow-birds about the vessels with brown

eaglets, and now and then a nelly, together with my having observed at different times birds flying to the S.W., which, although at a great distance appearing to be belonging to land, the water too of a light colour, I was in hopes of being near some considerable quantity of it, and on the weather becoming clear to the southward, saw much the appearance of land in that direction, and on going to the mast-head with a glass, I was confirmed in my opinion; but after standing some few miles south, the wind being E.S.E., the land vanished in a cloud, and in a short time after we were stopped by field-ice. Yesterday and to-day we have passed some of the largest icebergs I have yet seen, not being less than three miles in circumference, with the top surface smooth as a sheet of glass, while others are completely ragged; but I think that formerly they have formed one immense field. Saw an appearance of a high mountain, N.E., stood in that direction, wind E.S.E., but, as yesterday, it turned out a cloud.

Feb. 3.—The wind has been light so many days from the eastward that we have been able to make little or no progress. As to the southward, it is completely blocked up with fields of broken ice. Towards noon on the 3rd the wind gradually came round to the westward, our latitude 68° 30′, longitude 14° 42′ 15″, lunar 15° 20′ 30″, variation, by means of several sets of amplitudes and azimuths, 23° 12′ W., temperature, air at noon 33°, sun 60°, midnight 30°, water 34°. P.M. The breeze freshening from the westward, we steered S. by E., 6 knots an hour, until 11 p.m., when we entered much broken ice, and at midnight could distinctly see it running out as far as N.E. by E.; wore round to clear it. It now blowing a fresh gale, and the sea getting up very suddenly, we had much difficulty in getting clear to the northward, having struck against several pieces, though without any other damage than carrying away the martingale.

Feb. 4.—At 10 a.m., being clear of the ice, and the sea too high to venture again to the southward at present, we steered E.S.E., cutter in company, until 3 a.m. of the 5th, when we hauled up S.S.E. and S. by E., it being moderate and clear, but at noon again made the field-ice, hauled out, steering various courses. Passed either a large seal or an elephant, but it was too far off, and did not stay a sufficient time above the water to distinguish it properly. Many snow birds and brown eaglets about us, with some fin and hump-backed whale. Everyone expecting to see land, we saw or thought we saw many appearances of it. P.M. By several sets of azimuths and amplitudes, the variation was 29° 10′ W. The wind gradually died away, and at midnight was quite calm, and the water in a freezing state all round the vessel. I took up a considerable quantity of ice from the surface, about one-quarter of an inch thick, and melted it into two bottles. The temperature of the air at this time was 24°, surface of the water 30½°, at a depth of 250 fathoms 33°; as we had made little way since noon, our latitude was about 68° 50′ S.,

longitude 23° 00″ E. The field-ice about one mile to the southward. We saw several birds, which the sailors call king birds, the last two or three days, and which I think are of the same kind which I mistook for land birds a short time ago; but I understand they don't go a long way from the land.

Feb. 6.—The wind continuing light from the westward, the ice still continued to thicken, the motion of the water merely preventing it from forming in one mass, it forming itself into round patches of considerable diameter, and as I now saw some strange birds, which had some appearance of snipe, sitting on it, I shot three of them from the vessel, and on sending the boat for them, the ice was found so thick, the people could scarcely pull her through it. We likewise passed through several patches with the vessels, which absolutely stopped their way. I took some pieces into the boat which were nearly an inch thick, and I am convinced were the produce of the last 24 hours, and had we been becalmed one week, I am certain both vessels would have been frozen in fast. On filtering the ice taken up in the boat, in a temperature of about 45°, the salt part ran off and left a small quantity of perfectly fresh water, which perhaps may account for fresh water being got from ice formed at sea. At midnight we were obliged to haul out N. by W. ½ W., we having stood to the southward during the day into a large bay of field-ice. After clearing it to the northward we again hauled up S.E., but were obliged again to haul out. During this day we steered an easterly course with little variation along the edge of the ice. Saw a Port Egmont hen flying about the ice, and which passed close over the vessel. The water much discoloured (but no soundings at 250 fathoms), and many other indications of land. Many hump and fin-backed whales in sight. I now found the ice tending considerably to the northward, but found it impossible to pass through to the southward. On the 8th, at noon, our latitude was 67° 12′ S., and longitude by chronometer 27° 00″ E., lunars 27° 37′ 30″, by dead reckoning 28° 44′ E., temperature of the air 33°, in the sun 84°, water 33°. The wind westerly, with fine, clear weather, the ice generally from one to five miles to the southward. Saw an albatross this afternoon.

Feb. 9.—A.M. Saw a seal; the weather continuing fine with intervals of calm. At noon a breeze sprung up from N.E., but towards evening hauled more to the eastward, and during the whole of the 10th and 11th was strong from E.S.E., with thick weather, standing off and on the ice, but with little progress, and I am sorry to find the daylight begin to shorten very fast, and fear it will be impossible to get any further to the southward this season, as the ice for some days has taken a northerly direction, running into deep bays and out into points to the northward. Passed some large icebergs. Saw a few of the nelly species, brown eaglets and snow birds. P.M. 11, made field-ice. Stood to the N.E.

Feb. 12.—A.M. 1.30, stood to the southward. At 4, field-ice. Stood from W. to N.E. by E. At 6, passed through a considerable quantity of field-ice. At noon, fresh breezes from E.S.E. Weather rather clearer. Latitude at noon 66° 57′, by dead reckoning 66° 45′ S., longitude by chronometers 31° 38′ 15″ E., dead reckoning 33° 22′ E., making a current to the south-west, 28 miles in 2 days. Temperature of the air at midnight 32°, noon 32°, water 33½°.

Feb. 13.—Wind moderate from S.W. Hazy weather. Many nellies and blue petrel about us.

Feb. 14.—Light variable weather. At 4 p.m. sent the boats for some ice for present use. Passed through much straggling ice. At 8 passed through what seemed to be the most eastern point of ice. The weather being clear for a considerable distance, I was in hopes of making good progress to the southward, as a smart breeze sprang up from the eastward. I saw a large seal in among the ice. A.M., at 4.30, after standing about thirty miles S.S.E., made compact ice ahead, running away to the westward into a deep bay. Stood to the northward, the ice tending for a good distance on our weather beam to the N.E.; towards noon freshened to a brisk gale from E.S.E., and became very hazy with continual showers of snow. At 1 p.m. the cutter bore S.W. by W. about three-quarters of a mile, but, the weather becoming more thick, could scarcely discern. Took in all sail except the close-reefed mainsail and foretopmast staysail; at 3 it blew as heavy a gale as I almost ever witnessed from the S.E., with a high and running sea. The cutter not in sight. The weather was now so thick we could scarcely see a cable's length, passed several pieces of drift-ice, which with some difficulty we cleared, either of which with the sea then running would be sufficient to send us to the bottom; and being amongst a considerable number of ice-islands our situation was perilous, and we passed a very anxious night. It being now dark, between 10 and 2 o'clock, the wind, with the decks being wet with salt water and freezing on everything it touched, made it extremely cold and uncomfortable, and had not Captain Christie supplied these poor fellows with boots at Gravesend, I am certain they would half of them have been laid up. Towards midnight the wind moderated but left a heavy irregular sea, which caused us to knock about and strain a good deal. Tacked to the southward to look for the cutter.

Feb. 16.—On the 16th wore round occasionally to keep our position, but could see nothing of her. The wind more moderate than yesterday, but sea still high. At 8 p.m. wore to the northward. Wind, S.W. by E. Ditto wind, but still very hazy. Latitude by dead reckoning, at noon, 66° 44′ S., longitude, dead reckoning, 38° 05′ E.; from L.O. 36° 57′ E. Temperature of air, at 30°; at noon, 31½°. At 1 p.m. tacked to the southward. Clear weather and light winds E.S.E.

Feb. 18.—At 5 a.m. of the 18th, entered a large cluster of ice-islands, and at 5.30 made compact field-ice. Stood to the N.E. along the edge

of it. At 8, saw the cutter at a great distance in the N.W., the weather being very clear; bore up to close her. Noon, hauled to the wind. Latitude by observation 67° 50′, by dead reckoning 67° 29′; longitude by observation 36° 38′ 45″ E., by dead reckoning 38° 38′ E., making a current S.W., 28 miles in 4 days, although I think the error is more likely to arise from the reckoning during the last gale. At 2 p.m. stood to the southward, the cutter N.W. about three miles. The officer of the watch this morning saw some hair seal a short distance from the vessel, but as they stayed only a short time above water I did not see them.

Feb. 19—The whole of these 24 hours the wind was very light and variable, but generally from S.S.E.

Feb. 20.—On the 20th, the weather the same, with an easterly swell. Crossed Captain Cook's track in 1773, so that the ice which he saw remains in the same position as in that year. Our latitude at noon 67° 12′, longitude 38° 45′ E., we having made a N. 59° E. course, 56 miles since yesterday, at which time we saw the ice, and have not crossed his track more than 30 miles to the northward; I should like to have passed exactly the same spot, but the wind being very light from S.S.E., could not without much loss of time, and which is now, from a succession of light and contrary winds, become very precious. I left the deck this night about ten minutes before twelve, and it appears that shortly after the officer of the watch observed something in the sky resembling Aurora Borealis. At 1 a.m. he reported it to me, but on going on deck I found it was entirely dispersed, and was much disappointed at his neglect.

Feb. 21.—Light variable winds as yesterday. Very few icebergs in sight. Temperature of the air 32°, water 32°.

Feb. 22.—Light airs from the southward with calm, clear weather. Two icebergs in sight. Variation per azimuth 40° 22′ W. Saw a hair seal.

Feb. 23.—Light airs from the E.S.E., and calms the whole of these 24 hours. Saw several hair seals. At 10 p.m. saw a faint appearance of the Aurora Australis, which appeared to form in a yellowish-green arch from E.S.E. to S.S.W., but was very faint and continued but a short time, as it eventually disappeared at the setting of the moon, which was very clear and bright.

Feb. 24.—Moderate breezes with snow squalls. The wind veering from E.N.E. to S.S.E. Latitude at noon 66° 08′ S., longitude 43° 54′ 15″ E. Temperature 30°. Variation 40° 22′ W.

Feb. 25.—The wind became more steady from the eastward, although with repeated snow squalls and cloudy weather. At 8 p.m. saw an appearance of land to the southward, with many ice-islands, field-ice, and with much straggling pieces about us. At 9, the weather becoming thick and squally, tacked to the northward. At 10.30, more clear. Stood

to the southward through much loose ice. At noon our latitude was 66° 29′ S., longitude 45° 17′ E.; that which lately had the appearance of land now bore from E.S.E. to W.S.W. (true bearing), with a large range of field-ice stretching to the N.E. Innumerable icebergs, and the vessels so encompassed with straggling pieces we could proceed no further with safety owing to a strong N.E. swell, which set towards the main body of ice, which it now proved to be; the appearance of it was, I think, nearly similar to the North Foreland, and I should think the cliffs of it, which bore the marks of icebergs having been broken from off it, and which was exactly similar to their sides in every respect, was as high, or nearly so, as the North Foreland; it then ran away to the southward with a gradual ascent, with a perfectly smooth surface, and I could trace it in extent to at least from 30 to 40 miles from the foretop with a good telescope; it was then lost in the general glow of the atmosphere. As I observed some two or three lumps which had the appearance of land from the irregularity of their surface, I lowered a boat, and went myself to ascertain whether or not there was any appearance of land on a nearer view, judging myself to be about 3 miles at this time from the main body; but after pulling about half an hour or more, I found we were rather more than half a mile from it still, with the ice so thick we could at times scarcely get the boat through it, and as both vessels were hull down, and entirely at times hid from us by the ice, the weather also having a black appearance from the northward with a heavy N.E. swell, I deemed it most prudent to return after having fully convinced myself this was nothing more than a solid body of ice. I saw nothing near it except a few penguins, and shortly after getting on board observed a young elephant on a point of field-ice we were then passing, and which I went in the boat and shot. It proved to be of the same species we had seen from the vessels at different times, and which we supposed to be hair seal, and gave about 4½ gallons of oil.

I have long been anxious to ascertain as nearly as possible the origin of icebergs. It is the given opinion of most navigators that they are formed contiguous to land, and Captain Weddell mentions one in his southern voyage, which had so much black earth about it that he could scarcely satisfy himself it was not a rock. But of all the icebergs I have seen, which are many hundreds, I could never discern the least trace of their having ever been connected with land, and had formed the opinion in my mind that they originated from a vast body of ice, frozen on the surface of the water, and accumulating with time, and I should have regretted much had I been obliged to leave these southern parallels, from the advanced state of the season, without satisfying myself in this particular, and having seen nothing but the field-ice. However, this morning has completely satisfied me in this respect, for I have not the least doubt that the whole spaces, from the latitudes I have visited to the Pole, are one solid mass; land may intervene, or winds, where they are

strong and prevalent, may have prevented its forming in some parts more than others, but I have found such frequent calms and light airs with smooth water, that I see no reason why ice should not be formed to any extent during the winter seasons, and if, as I have before observed in my remarks, it could form in the month of January, in latitude 68° S., of the substance of half an inch in one night, what might it not do in the month of July under the same circumstances? As to the icebergs being formed on shore, I do not think it possible or probable for this reason, their own weight would prevent their accumulating on any prominent part of land. It would break off at different times and form what is called field-ice, for should it once become so extensive a mass as an iceberg, and which could only be when there was shallow water, it is utterly impossible it could ever separate from the land where it was first formed, as it is well known that ice swims at least two-thirds under water; indeed I have been astonished at some pieces which were not more than six or seven feet above the surface, that swam so deep I could scarcely trace their bottoms in the water; as to the ragged tops of icebergs, it may be accounted for in this way: after a portion of ice has been separated from the main body by a gale of wind, or some eruption, or other natural cause, its surface, as I apprehend, is always perfectly smooth, at least all those which appeared recently separated were so, while the others which were sodden with salt water had smooth parts in them with occasional peaks, and in other parts completely honey-combed, which in my opinion is to be accounted for in this way: that as the water is generally found to be one or two degrees warmer than the atmosphere, together with the continual motion of the iceberg, which is sometimes considerable—at least the water has great motion near its edges, and breaks over it with great force—the lower part becomes sodden and undermined, and its softer parts give way to the force of the sea, break off and rise to the surface, which forms the field-ice.

After this continual decay below has gone on for some time, the lower part becomes unable to sustain the weight of the upper; it becomes too heavy and capsizes, which shows that rugged appearance I have before mentioned, and should it be blown far to the northward, it turns over and over occasionally until it entirely dissolves, but I don't think the upper parts decay. I have observed several where the sun at times had the power to dissolve them a little, but from a change of wind or other circumstances it was again frozen into an icicle, which had a beautiful effect when the sun was shining on it; some have appeared to have been a long time drifting about, as several distinct layers of snow were perceptible on them, and those which appeared to be turned over were washed in places as smooth as a vessel's bottom, and sometimes not unlike the shape of one, with a smooth layer of snow over it, which froze as it fell, some forming arches, &c. Field-ice is

I believe, likewise formed from the upper parts of icebergs, as on Sunday, the 20th inst., the vessels were very near a large ice-island, and while looking at it I observed a large mass of ice break off from one of its upper projections and fall into the water with a tremendous noise, and which floated in large lumps on the surface, so that the breaking up of one or two of these icebergs would make a considerable patch of field-ice.

Observing a large range of complete arches in this iceberg with many other cavities, I fired a cannon shot at it to see what effect it might have; but the motion of the vessel at the time of firing carried the shot just over its surface, when a complete cloud of snow birds rose from it, which in all probability had laid their eggs there. The second shot was more successful, but had no other effect than knocking off a few small pieces of ice. I pulled round this iceberg in a boat very close, but could observe no symptom of its having ever been in any way attached to the land.

I have been likewise much surprised at the constant easterly winds which prevail on these meridians, as it is generally understood to the southward strong westerly winds prevail, but I have a beating passage of it, which with the frequent calm, now and then a strong blow from the S.E., with generally a heavy swell from that quarter for some time before and after, together with the thick weather, incommode me very much.

Feb. 26.—A.M. Squally and cloudy. Wind southerly. At noon latitude 65° 57′, longitude 46° 17′. Passed some straggling ice. Many icebergs in sight. P.M., wind more easterly. Stood to the southward. 8 p.m., thick weather with an easterly swell. Tacked to the northward, it being too thick to venture among the ice. Cutter in close company.

Feb. 27.—Moderate breezes from the S.S.E., with a most distressing E.S.E. sea, which made the vessels pitch and strain very much, and were enabled in consequence to carry but little canvas, accompanied by thick weather. Repeated showers of snow. Many small birds about us.

Feb. 28.—In the morning more regular sea. Tacked to the southward. Wind S.E. Noon, more clear. Latitude 65° 57′ S., longitude 47° 20′ 30″ E. P.M., passed to the southward through much broken field-ice. 4 p.m. saw several hummocks to the southward, which much resembled tops of mountains, and at 6 p.m. clearly distinguished it to be land, and to considerable extent; to my great satisfaction what we had first seen being the black tops of mountains showing themselves through the snow on the lower land, which, however, appeared to be a great distance off, and completely beset with close field-ice and icebergs. The body of the land bearing S.E.

March 1.—During the whole of this day, and the 2nd, we were

employed in endeavouring to work a passage through the ice, but after many fruitless attempts and some heavy blows, were always frustrated. P.M. As our attempts to near the land every hour opens some new object to us, and seeing a bluff point in S.E. which has every appearance of a cape, I still have hopes of accomplishing my wish. Latitude, at noon, 66° 7′, longitude, 49° 6′ 30″ E. The main body from S.W. to S.E. about twelve leagues (nearly calm), having stood far in among the ice, I found some difficulty in clearing it again, and as the calm had lasted several hours, the sea froze to that excess that on the morning of the 3rd we found it at least an inch thick over the whole surface of the water, and which impeded our progress through it very much.

March 3.—Thermometer, air 32½°, water 30°. At the same time, nearly the whole night, the Aurora Australis showed the most brilliant appearance, at times rolling itself over our heads in beautiful columns, then as suddenly forming itself as the unrolled fringe of a curtain, and again suddenly shooting to the form of a serpent, and at times appearing not many yards above us; it was decidedly transacted in our own atmosphere, and was without exception the grandest phenomenon of nature of its kind I ever witnessed. At this time we were completely beset with broken ice, and although the vessels were in considerable danger in running through it with a smart breeze, which had now sprung up, I could hardly restrain the people from looking at the Aurora Australis instead of the vessel's course. Having on the 3rd, in the morning, hauled round to appearance the easternmost part of the firm ice, with the wind at S.W., and after a run of about fifteen miles due S., having entered a narrow channel of about three miles broad, formed on the west side by an immense chain of ice-islands and on the east by firm field-ice, and seeing an opening ahead from the mast-head, was in great hopes to find a passage direct to the land, but at 6 p.m. found it blocked up in every direction, nor have I been able in any one place to come within 30° of it; hauled out to the northward, and at 10 p.m. came into clear water, and on the 4th steered along the edge of the field-ice. Our latitude by observation at noon, 65° 42′ S., longitude 49° 29′ E. The cape, which I have named Cape Ann, by bearings at 4 p.m., being in latitude 66° 25′ S., longitude 49° 17′ 45″ E. At 6.30 a breeze sprung up from S.E. with squalls. At midnight freshened to a stiff breeze, and at 4 p.m. of the 5th blew a fresh gale with thick weather shortly after. We lost sight of the cutter, bearing about west by north two miles. The gale increased, and at 12 blew a perfect hurricane, which lasted without intermission until the morning of the 8th. The weather during the whole time was so thick that we could scarcely see twice our own length in any direction, and being so close to ice of every description, were in a very dangerous situation, the vessel being at the same time a complete mass of ice, and the wind blowing so intensely cold, it was impossible for the people to hold

anything in their hands for more than a minute or two at a time. Our larboard quarter-boat was washed away. Our bulwarks, starboard quarter-boats, quarter-deck rail stove in, the boats being up at least above four feet above rail cloths, but by the blessing of God we drove clear of all the icebergs, only seeing one close on our weather bow, our head the whole time of the gale from E.N.E. to N.E., and had we fallen a little to windward of any large iceberg, or any quantity of field-ice, must have all inevitably perished, as the vessel was unmanageable, and when the weather moderated on the morning of the 8th, left us almost a wreck. At 8 a.m. wore round to the southward. At noon our latitude by observation, 63° 49′, longitude 47° 00′ 00″ E., having made a drift of 120 miles N.N.W. during the gale. P.M. The weather still wearing a threatening appearance, the wind at N.E. I stood to the southward under easy sail, not to run the risk of being caught on a lee shore should it blow hard from the northward. I have had several men hurt [and] have now four or five on my list for cure. I am under much apprehension for the cutter, as I think this is the hardest blow I have ever known with the exception of the hurricane of 1814.

From the 8th to the 14th, strong S.E. gales, with generally one in 24 hours, a few hours interval of calms. Snow and sleet in great abundance nearly the whole time, so that when we had a few hours fair wind the weather was too thick to make much way towards the land, as the gales succeeded the calms very suddenly.

March 15.—P.M. Dry weather. Passed very close to large piece of ice about a ship's length, but thank God cleared it safely. At noon, latitude 64° 43′ S., thermometer shade 25°, wind S.W. by S. Clear weather.

March 16.—Stood to the southward. Latitude, at noon, 65° 16′; longitude, dead reckoning, 49° 27′ E.; temperature, air 24°, water 30°. P.M. It freshened to a gale at S.E. Wore to the northward. At midnight stood to the southward, the weather being moderate, and at 8 a.m. saw the land bearing south by compass, which was a very high mountain. Cape Ann was shortly after observed to bear S.W. At 6 p.m. made field-ice, and thick clusters of icebergs ahead, and 4 points on each bow, but am sorry to say could see nothing of the cutter. Our latitude at this time was 65° 44′ S., longitude 50° 09′ E. Cape Ann W. by S. High land about ten leagues south by compass. Temperature, air 22°, water 29°. Wind, N.E. and moderate, and as I observed little or no difference in the position of the field-ice since the S.E. gales, I feel myself absolutely obliged to give up all further pursuit in this part. The land inaccessible, heavy gales frequent every day, some of the people getting sick, the carpenter for some time past having lost the use of his legs, and two others at this time in the same situation, and two or three more under medicine for the same complaint, although every attention has been paid to their health and comfort. The vessel is very uncom-

fortable in bad weather and ships a great deal of water, and is now on her outside, both hull and ropes where the spray can reach, one mass of ice; but as the land has hitherto tended to the north-eastward, I am still in hopes to fall in with it in that direction clear of ice, as I have still a great space on the charts unexplored. From this time until the 22nd, we had S.E. gales with little intermission, and consequently were enabled to make but little progress; on the 23rd the wind came round to N.W. by W., which enabled us to make a run of 87 knots to the eastward; but during the day it again shifted, and blew a hard gale on the night of the 23rd and the 24th from E.S.E. to S.S.E. with a heavy sea on. Our latitude L.O. noon 62° 26′ S.; longitude 52° 24′ E. Temperature 32°, and I much fear shall have no more fine weather this season, the nights intolerably long and dark. The Aurora Australis has made its appearance several times, and sometimes very brilliant, which I took to be an indication of wind. For some days back we have had many birds about us.

March 25.—We had hard gales from S.S.W., the weather still continuing very thick. On the 26th the wind came round to E.S.E. again, with fresh gales and squalls. Towards noon it calmed.

March 27.—Strong winds S.E., squally with much snow and sleet, intervals of calm, which left a most distressing sea; a great quantity of black eaglets and other small birds about us. Very thick weather at times.

March 28.—During the night the weather became clear, with a moderate breeze from the northward. At 8 saw the appearance of land S.S.E. Towards noon the weather thickened, and blew a strong gale from N.N.E. Wore round to the N.W. to wait for clear weather. Latitude, L.O. 60° 43′, dead reckoning 60° 33′; longitude, L.O. 55° 17′ E. I have not had an observation since the 14th. I have six of the crew laid up with pains and swellings in their legs.

March 29.—Strong breezes. All night from the northward, hove to. Daylight, bore up S.E. Noon, altered course to S.S.E. No land in sight. P.M., ditto weather.

March 30.—Strong gales from N.E. to N.N.W., with frequent squalls of snow and sleet, and for the most part very thick. Bore up and hove as the weather required. Passed several ice-islands during these gales. P.M., ditto wind. Altered course to south. Daylight, bore up and made sail, steering south. Noon, moderate. Latitude by observation 59° 50′, from last observation 60° 55′. Longitude by chronometer 61° 28′, from last observation 60° 46′, which gives a current north 33° E., 78 miles in 15 days, but in all probability the error arose from the continual gales we have had since our last observations. 8 p.m., thick weather, hove to. Daylight, bore up S. Moderate breezes from the northward, with showers of snow and a heavy swell. (I very much fear several of the crew have got the scurvy.) Noon, latitude by observation 60° 38′ S., longitude by chronometers 63° 08′ E., temperature 34½°.

April 2.—Moderate breezes from the northward, but very squally, with much snow. During this night the Aurora Australis was exceedingly bright, having the appearance at times of the opening and shutting of a fan and various other shapes, moving almost with the quickness of lightning, and at times only a few yards above our heads, and had more the appearance of illuminated mist blown about by furious whirlwinds than anything else I can compare it to; indeed, more or less, it makes its appearance nearly every night.

April 3.—We had the wind northerly with showers of snow. Latitude at noon 62° 12′ S., longitude L.O. 66° 24′ E. On the 4th our latitude at noon by observation was 62° 23′, longitude 68° 05′ E., temperature 28°, winds light, N.N.E., but towards the afternoon the wind came round to the southward with much snow and thick weather, and at midnight blew a heavy gale from S.E., which during the 5th hauled round to the S.W., and continued to blow with great violence until the 6th, a.m., when it moderated, and again came round to N.N.E. I had hoped to find land from the general appearance of that I had left in about 61° S. and 65° E., but finding nothing on the 4th, 62° 23′ S., longitude 68° 00′ E., and experiencing nothing but heavy gales from S.W. to S.E., anywhere beyond the latitude 62° S. The vessel, now a complete mass of ice, only three of the crew who can stand, and likewise being well convinced that any land to the southward of that latitude would be inaccessible, I find myself from these most imperious considerations obliged, although very reluctantly, to give up any further pursuit this season, and as I have observed nothing which in my opinion can authorise me to wait here for another season by wintering at the Island of Desolation, I consider it most prudent to proceed to New Zealand in prosecution of my voyage, and to get into a climate more settled as soon as possible to reinstate the health of my crew, the whole of whom I have now put on fresh provisions, which, should it be the scurvy they have, will, I hope, at least prevent its spreading any further. From this time until the 14th we had very unsettled weather. The wind from N.N.E. to N.W., blowing in squalls and heavy gales nearly the whole time, and the nights so exceedingly dark, except when illuminated by the Aurora Australis, that I found it necessary to lay-to every night. On the 15th the weather became more moderate, but left a very long north-westerly swell, which prevented us seeing in the night more than two or three cables' length.

April 16.—Still continued squally with hail, though generally fine, and a heavy westerly swell. Our latitude at noon being 54° 49′ S., by observation, longitude 90° 3′ 45° L.O., and this being about midway of Captain Cook's tracks, should the weather prove fine, I intend to run along on this parallel. (Two of the crew complain very much.)

April 17.—Wind northerly with heavy squalls. Much snow and sleet with thick weather, which obliged me to heave to every night, the wind always bringing a high sea with it, which kept our decks continually

afloat, and continued to blow between west and north until the 21st, when it became more steady at N.W. and clearer.

April 22.—Ditto wind. Our latitude at noon, by observation, 54° 57′ S., dead reckoning 54° 10′, making a difference of 4° in ten days, and of latitude 45′ in five days, which I think is to be attributed to great decrease of variation as well as not allowing sufficient distance in the courses, as the sea has generally been very high and running after the vessel; and by an azimuth this afternoon I found the variation only 27° 38′ west, which is a decrease of 15 degrees since the last. 8 p.m., the Aurora Australis is very bright, stretching in the form of a rainbow from E.S.E. to W.S.W. During the last few days I have observed a new species of eaglet with * * * * head and body and black wings.

April 23.—Strong north-east gales with thick weather, which lasted all the 24th. At 5 p.m., this day, died Henry Brown, the carpenter. He had had a long illness, which commenced with pains and swellings in his legs. Afterwards his mouth became much affected, the gums swelling over his teeth, and a general debility ensued. When he died his mouth was in a putrid state. I regret very much the death of this man, as he was very useful and had good abilities.

April 25.—Moderate breezes from the northward with a heavy sea running.

April 26.—Strong northerly winds with hazy weather, and having now only one of the crew able to stand, together with one boy, the officers (two mates) and myself, I find it absolutely necessary to make the best of my way for Van Diemen's Land to save the vessel and the lives of those who remain.

April 27.—Passed some kelp, and at several times saw and heard penguins. From this to the 30th the wind was light, with much rain, when it blew a strong gale from N.E., with heavy and frequent hail squalls. P.M. Died, John Antonio, a native of the Cape Verde, of dysentery; the others of the crew in a very dangerous state. Strong N.W. winds. Latitude by observation, being the first for some days, 52° 58′, by dead reckoning, 51° 36′, which shows a great decrease in variation.

May 2.—Longitude L. O., 126° 32′ 45″ E. On the 2nd of May the wind came more to the westward, which enabled us to haul up north-east by north, as there is now, I find, no variation by the observations, or if any, easterly. This is very acceptable, as one of the mates complains very much, and has evident symptoms of scurvy. Our latitude at noon, 51° 53′ S., longitude by chronometer, No. 2, 134° 40′ 00″ E.; by L. O., 129° 09′ E.; by dead reckoning, 126° 40′ E., which great difference, I conclude, must be from error in reckoning and allowing the course too much to the northward.

May 3.—Strong westerly gales with hard squalls and much hail. Heavy running S.W. sea, which lasted with little variation till the 6th, a.m., when it became more moderate. Latitude by observation, at noon,

44° 36′ S., longitude by chronometer, No. 2, 144° 12′ 30″ E. At 5 p.m. hove to, and at daylight of the 7th saw land bearing from N. to N.W., p.m. Light airs from N.N.W., with long westerly swell. At 5 the extremes of the land bore from N. ¾ W. to north-west by W. ¼ W., which by cross bearings gave the entrance into Storm Bay, N.N.W. about 30 miles. By ditto, ditto, Rurick's Rock, S.W. about 10 miles. The people continue much in the same state for some days past. The wind continued from the north-west with a heavy swell, blowing only at intervals and then falling calm, which made it utterly impossible to near the land, the swell and current at the same time carrying us away to the S.E., and at 8 p.m. on the 8th we had drifted at least 20 miles in a S.E. direction; under the conviction that should we be blown away from this land it was hardly possible for us under the present circumstances to reach any other, I endeavoured all in my power to keep up the spirits of those on board, and often had a smile on my face with a very different feeling within.

May 9.—On the 9th, in the morning, the wind came round to the S.E. and gradually increased; the form of the land clearly showed Storm Bay open, but the headlands had nearly sunk below the horizon. At 6 p.m. we were within Tasman Head, and as I expected the wind would die away on approaching the bay, I ran in without fear, but about this time it came on to blow and rain very hard. The sea got up almost instantaneously, and as the night came on very dark, and being an entire stranger without any directions for entering the port, and having no other guide than a plan of the bay by chance I found among the other charts. Although my situation was so precarious, I should have been most happy had I been 30 miles further at sea. However, by excessive hard work, veering round when I saw land or the glimpse of land on either side, at daybreak I found myself in a very good situation for running in for the mouth of the Derwent.

May 10.—Although it was still very thick, and on entering the river I saw a flagstaff and made a signal of distress, but received neither pilot nor assistance till within three or four cables' lengths of the ships at anchor in Sullivan's Cove, when the pilot came on board, and almost immediately after the *Lively* (Captain Weddell) cutter with eight or ten hands, and moored the vessel.

The moment the proper authority had been on board I went ashore, and having no agent here, I applied to Mr. James Grant, who is agent for Lloyds, as the most proper person I could apply to.

However, he declined doing anything personally, but introduced me to Mr. Anthony Fern Kemp, who on being informed of the circumstances of the voyage and the owners, immediately consented to undertake the agency of the vessel, and took immediate measures for getting the people into the hospital, and by 4 o'clock p.m. I had the pleasure of seeing them all safely admitted and taken care of.

II.

Voyage across the Pacific and Discovery of Graham Land.

1831. *Oct.* 10.—At 8 a.m. weighed and stood out of Sullivan's Cove in company with the *Lively*, Captain Weddell. Messrs. McMichael, Thomson and several other gentlemen came on board to breakfast and now took their leave.

* * * * * *

1832. *Jan.* 4.—On the 4th January were in latitude 56° 26′ S., longitude 172° 45′ W., with light variable winds, and being now in the latitude in which I had hopes of falling in with land, I determined to keep within this parallel for some degrees to the eastward. On the 5th saw some albatross and some smaller birds, and at various times passed kelp in small quantities. At noon the wind was strong from the eastward, with thick weather. On the 6th much rain. Saw 2 seals. The weather still thick. Wind south-east by east. I continued in this parallel until the 11th, the weather all this time being very thick, and endeavouring as near as possible making a N.E. and S.E. course, so that should any land be near I could not possibly pass it, at the same time running some risk, and as the Nimrod Islands were now in my track, I had great hopes they were in existence, and steered various courses to fall in with them. These islands, as laid down in one of my charts, agreeing with the latitude in which I had expected to find land. Latitude by observation at noon 56° 03′, longitude 157° 50′ 22′, means of all the chronometers. Continued making an easterly course until the 14th. The weather still foggy, when there was every appearance of being on a bank—sounded, but no bottom.

Weather more clear and many birds about the vessels. Passed some kelp occasionally.

Squalls of snow from the southward. Barometer 29° 30′, thermometer, air 39°.

On the 17th strong westerly winds, some blue petrel in sight.

Thick foggy weather with rain. Barometer 28° 30′, thermometer 42°, latitude 57° 29′, longitude 143° 18′ W., and as I intended to cross Captain Cook's tracks and steer for a chance of making land to the W.S.W. of South Shetland, I gave Mr. Avery the requisite instructions in case of parting company.

Jan. 22.—Saw a Port Egmont hen, but it was soon lost in the haze, and could not determine what course it had taken. On the 23rd and 24th the wind was very variable and squally, with snow showers. On the 25th passed several icebergs, with variable winds, which were succeeded by strong southerly gales. The barometer for several days standing at 29°, with little variation, mean temperature, air 37°.

Jan. 28.—Strong breezes from the northward with thick weather. Passed many icebergs. Latitude at noon 61° 32′, longitude 130° 55′, L.O. On the 29th, 30th and 31st passed through large clusters of ice-islands, about 100 each day, with some loose ice. Latitude at noon, 64° 21′ S., longitude 160° 27′ W., L.O.'s.

Feb. 1.—On the 1st of February the barometer fell to 27·70. The thermometer, air 35°, water 35°; about six islands were in sight continually. The weather cloudy, sea topping, squally from the S.W., and considerable fall of snow. The barometer continuing to fall, I made every preparation for a gale, as the wind hauled round to the eastward, and the appearance of the weather in every respect very threatening.

Feb. 2.—Hazy weather, with snow and sleet. Wind variable, but not strong. Latitude at noon, 65° 01′ S., longitude 114° 19′ W.; barometer, 27·45, at midnight, 27·30; thermometer, air 40°, water 36°. 3rd. Hazy weather, light easterly winds. Eight or ten icebergs always in sight. Saw two or three albatross. Latitude at noon 65° 32′ S., longitude 114° 09′ W. Barometer rose 27·80; thermometer, air 39½°, water 36°. P.M. The weather more clear, and every appearance of being fine. Observed the phenomenon of a large iceberg falling to pieces, which it did with the noise of a clap of thunder; being very near the vessel, the sea was immediately strewn with the fragments, and the iceberg appeared to be not one-half its original size.

Feb. 4.—Light, hazy, variable weather. The cutter being rather short of water, supplied her with six hogsheads, to prevent the crew drinking the ice-water, which I think tends much to produce dysentery. P.M. Mr. White returned on board from the cutter in consequence of some dispute with Mr. Avery, and the cutter's sails being in so bad a state, I find it absolutely necessary to make as quick a passage as possible; indeed I am well convinced that should land be found much to the southward of this latitude it would be impossible to get to it for ice, and although it might answer the purpose of discovery, would not be beneficial to these vessels, and the long and severe fogs, should the voyage be much lengthened here, would disable the crew for their necessary duty, should we find any land in the neighbourhood of Palmer's Land or South Shetland, or even afterwards about Cape Horn, and besides it would be throwing the remainder of the season away to little purpose. P.M. A few ice-islands about. The wind light from the northward, and thick weather on the 5th and 6th. The wind fresh from E.S.E. to S.E. During these two days we passed many clusters of large ice-islands. On the 7th the wind south, blowing a brisk gale. Latitude at noon 64° 30′ S., longitude 106° 33′ W.; temperature, air 35°, water 35°; barometer, 29·00. Variation per azimuth, 27° 57′ E. (a very rapid increase). On the 8th much snow and sleet. 9th, ditto weather. Strong N.W. winds, with snow, sleet and thick weather, which lasted till a.m. of the 12th, when it became more clear, and having passed

through from 150 to 200 icebergs every day for some time back, our navigation has been attended with considerable danger, being obliged to heave to and bear up continually, as the weather became more thick or partially cleared away. Several albatross about, besides a few Cape pigeons. Latitude at noon 66° 27′ S., longitude, by means of chronometers, 81° 50′ W. Mean temperature, air 36°, water 36°; barometer 29° 20′. Variation, per several sets of azimuths, 32° E., a difference of 18° when the compass was placed on the binnacle, and when on the quarter; having no convenient place amidships, of course I must abide by those taken at the binnacle. Several hump and fin-backed whales in sight occasionally.

Feb. 14—A.M. Saw a seal and a penguin and a few blue petrels. Came suddenly, about 1 a.m., upon close clusters of icebergs and much broken ice; obliged to steer N.E. for several hours to clear them, having not less than four or five hundred icebergs ahead and on each bow. P.M., about twenty ice-islands only in sight; temperature, water 34°, air 34½°; barometer 29·20°; latitude at noon 66° 30′ S., longitude L.O., 78° 04′ W.

Feb. 15.—On the 15th strong gales from the southward. Water smooth. Latitude at noon 67° 01′ S., longitude 71° 48′ W. At 5 p.m. saw land bearing E.S.E., which appeared at a great distance—run for it all night with a light breeze from the S.W. At noon our latitude was 67° 15′, longitude 69° 29′ W. The body of the island E. about three miles. Temperature, air 33°, water 33½°, at a depth of 250 fathoms (no bottom). Barometer 29·30°. This island being the farthest known land to the southward, I have honoured it with the name of H.M.G. Majesty Queen Adelaide. It has a most imposing and beautiful appearance, having one very high peak running up into the clouds, and occasionally appears both above and below them; about one-third of the mountains, which are about 4 miles in extent from north to south, have only a thin scattering of snow over their summits. Towards the base the other two-thirds are buried in a field of snow and ice of the most dazzling brightness. This bed of snow and ice is about 4 miles in extent, sloping gradually down to its termination; a cliff, ten or twelve feet high, which is split in every direction for at least two or three hundred yards from its edge inwards, and which appears to form icebergs, only waiting for some severe gales or other cause to break them adrift and put them in motion. From the great depth of water, I consider this island to have been originally a cluster of perpendicular rocks, and I am thoroughly of opinion that the land I before saw last year, could I have got to it, would have proved to be in the same state as this, and likewise all land found in high southern latitudes.

Feb. 15.—I now determined to stand to the N.E., supposing that 100 miles in latitude might make a considerable difference, and from

this island being cleared of all drift-ice by, I suppose, the prevailing southerly winds, others might be found more favourable.

Feb. 16.—We could see now high mountains to the southward, and, the weather being particularly clear, must have been at least ninety miles off. On this night and all the 17th the weather was very thick, which obliged me to stand to the N.W., and although there was scarcely a living thing to be seen near the island we had left, birds were now very thick about us. P.M. Hauled up N.E., having made a N.N.W. course about ninety miles.

On the 17th and 18th passed several small islands of exactly the same appearance as Adelaide Island. This range lays W.S.W. and E.N.E., and had no mountains on their tops, but a complete field of snow and ice perfectly smooth except near their edges. I could plainly see a tier of very high mountains in the background, which had a grand appearance.

Feb. 19.—At 4 p.m. I sent the boat to an island, which appeared to join the mainland, and some naked rocks lying off the mouth of a considerable entrance. I had great hopes of finding seal in them. At 10 a.m. the boat returned, not having found anything alive on the island, but having pulled quite round what Mr. White informed me was an excellent harbour for shelter, although a rocky bottom. I have named this island Pitt's Island, from the great likeness of an iceberg to that statesman in a sitting posture, and which for some time I took to be a rock. This island has many bays in it; the centre part of the west side, latitude 65° 20′ S., longitude 66° 38′ W., by good sights [and] chronometers. A heavy S.W. swell setting on shore prevented me from running between this and a smaller island to the N.W. towards the mainland, which I had at first intended to do. The weather became thick, and having many rocks in sight, hauled out to the westward.

Feb. 21.—On the 21st I again stood towards the mainland, and at 8 a.m. went in the boat myself and pulled into a large inlet; the bottom appeared to be rocky in places where it could be seen, but I found no bottom with 20 fathoms, but as we found no seal nor indeed anything but penguins and a few birds, I did not sound with a deeper line. This being the mainland, I took possession of it in the name of His Majesty King William the Fourth, the highest mountain I named Mount William on the same occasion; the next in height I named Mount Moberly, in honour of Captain John Moberly of His Majesty's Navy; the water was so still that could any seal have been found the vessels might have been loaded with the greatest facility, as they might have lain alongside many of the rocks perfectly secure. These rocks for the most part were clear of snow; the day being fine and the sun very warm makes it the more surprising that nothing was found upon them. On one of them I observed two young Port Egmont hens lying partly on the rocks and partly on the snow without either nest or shelter. On the

22nd and part of the 23rd it blew a severe gale from N.N.E. to N., and I hauled off the land with a press of sail. Towards the evening of the 23rd the weather became more moderate, but thick and threatening.

Feb. 23.—During this day and the 24th stood off and on shore as the weather cleared up.

On the 25th more clear, but nearly calm. Land from N.E. to east by south. Latitude at noon 64° 28′ S. Longitude by chronometers 66° 11′ 15″ W., by lunar ⊙ and ○ 65° 49′ 45″ W. Latitude of Mount William 64° 45′ S.

Feb. 26.—Longitude 63° 51′ W. On the 26th calm weather and clear with S.W. swell. Temperature, air 35°, water 36°. Barometer 29° 00″. A.M. of the 27th, squally appearance; saw the loom of land in the N.W., stood in that direction in hopes of better success. On the 27th the wind was moderate from the southward with squalls of snow. During this day and the 28th continued to make a N.W. course in hopes of finding land, but saw none in that direction. Supplied the cutter with water.

Feb. 29.—On the 29th of February, at 7 a.m., saw Smith's or James' Island bearing east by south ½ south. Strong northerly gales with thick weather. Heavy squalls and very heavy sea, which lasted until the 2nd of March, when the wind shifted to W.S.W.; finding the sea clear of ice I determined, if possible, to visit South Shetland, although the season was far advanced. I was in hopes, should no vessels have arrived here, I might still be in time to load the vessels with elephant and oil, as I now expected the March bulls would be coming up.

March 3.—On the 3rd of March at noon our latitude was 62° 08′ S. Longitude by chronometers 62° 17′ 45″ W. Temperature, air 36°, water 39°. Barometer 28° 56′. The entrance to New Plymouth S.S.E. ½ E. James' Island south by west. Midnight, strong gales from the south-west with heavy snow squalls. Noon of the 4th, ditto weather. Smith's Island S.S.W. Entrance to New Plymouth. South Shetland S.E. ¾ E. Longitude by chronometer at noon 62° 09′ W. Temperature of air 31°, water 34°. Barometer 20° 50′. During all this night heavy squalls of wind with snow. Noon of the 5th more moderate. At 4 p.m. entered the mouth of New Plymouth. Sent a boat to sound for an anchorage. At 6.30 came to in 5 fathoms water with the best bower. Found lying here the schooner *Exquisite* of London. From Captain Kellock I understood this anchorage was quite secure, and on the 6th it certainly appeared so. After I had hauled the vessels closer in shore, moored the *Tula* with 45 fathoms of chain upon each anchor, she being then completely land locked.

Understanding there were plenty of elephant on the beaches, I lost no time in looking for them, and on the 7th sent away two boats, which returned next day loaded, having met with about thirty elephant, which were killed. Conjointly with the crew of the *Exquisite*,

the boats continued to work briskly for a few days, but tl only animals up, with the exception of a few stragglers put a stop to.

March 11.—On the 11th, I found no prospect of doing . with the boats, and determined to fit the cutter out a. different islands to the southward. On the 17th the *Exq* London, and on the 18th I went out with the cutter. H my stay in New Plymouth, the wind had been from the but without bringing in any considerable sea, so that I *Tula* perfectly safe while I should be away with the . stood for James', or Smith's Island, but found nothin Snow Island, the South Beaches, etc., etc. But on Snow eleven pup elephants and at the great risk of losing the The weather has been so bad since my leaving the examining these islands occupied me till the 2nd of Apri I again anchored in New Plymouth, having been several boat on the cutter, and under considerable anxiety for away. On my return the mate told me he had be apprehensions for the vessel, as the swell had set into tl heavy a few days before. We now set about fitting bot the cutter I intended sending to England, and to procee to the nearest sperm ground, which together with waterii us till the 10th, when I had everything in readiness. I back the wind had been very strong from the N.W., N.E from the southward, which brought in occasionally a c to the anchorage. At the same time the breakers betv and Ragged Island were terrific, and on the opposite si. On this day the swell increased very much, owing to tl shifting from N.W. to N.E., which appeared to set the s into this anchorage from the opposite side of the sou *Tula* struck abaft. I immediately veered away the insho on the starboard one, but the vessel still continuing t and aft, I let go the sheet anchor and again hove in on in hopes to shoot her ahead. She now remained som striking, and I was in hopes the danger was over, but in still heavier and the water falling, she began to str and the rudder was carried away from the stern post; f could not do anything more for the safety of the ves my thoughts to the safety of the crew; and at 10 p. the rudder in the best way I could, and after embarki boats to be sent aboard the cutter with much diff necessary to abandon the vessel for the present, and I people on board the cutter. During all this time, from we could get, we never had less than 4½ fathoms vessel not drawing more than 10 feet water forward,

During the whole month of December, the midsummer of these latitudes, the weather here was very stormy, with heavy rain, but the vessels laid secure in Port Chalky, or Port Souta, an excellent harbour, rather more than 3 miles long by 1 broad, on the south-eastern side of Chalky Bay, and were fully occupied in refitting, watering, etc., and making every preparation for their sealing voyage to the Frozen Ocean. In speaking of Chalky Bay, Captain Balleny says:—

"When about 5 or 6 miles to the westward of Cape West, one sees the white cliffs of Chalky Island lying near the middle of the entrance; yet the cliffs are not of chalk, as might be supposed from the name, but of hard white rock. In running down to the S.S.E. from Cape West you see the Table Rock (always from 10 to 12 feet above water) broad on the starboard bow. Now, by the plan of Chalky Bay,* given to me before my departure from England by Captain Washington, Secretary to the Geographical Society, when 2 miles off Cape West the Table Rock appears shut in with the south point of Chalky Island, whereas it should be placed more than a mile farther west, or bearing S.S.W., and not S.E., of the south point of the island. South-easterly from the Table Rock extends a very dangerous reef, on which the sea in bad weather breaks furiously, and at the southern extremity is a rock always above water: this reef, about a mile long, extends directly across the entrance of Chalky Bay, so that all ships ought to make Cape West.

"There is no hidden danger in beating up the bay, but the soundings laid down are all imaginary: there are no soundings till within a few yards of the rocks. I worked up the bay with the deep-sea lead going all the way, and I never yet struck the bottom. Only twice the schooner's length from the rocks, abreast of the cascade in Deep Bay or Cunaris Arm, we had an up and down cast with 80 fathoms and no bottom, yet it is marked on the chart 10 and 7. The entrance into Port North is narrow but deep, and at the top shoals till there is scarce water for a boat. Edwardson's Arm forms a splendid harbour. Port Chalky or Port Souta, on the south side of Chalky Bay, is the harbour generally used by ships visiting this part of New Zealand. In the entrance, and nearly in the middle, but rather nearer Garden Island, is a rock just visible at high water. Looking up Port Chalky, the first bight or bend of the land on the left is called Ship Cove, and off the point, where 10 fathoms are marked, a reef runs up the harbour nearly one-third across the cove. The *Eliza Scott's* anchor was let go in 8 fathoms, and when she swung she struck on the reef: about three times the ship's length from the reef we had 22 fathoms. In mid-channel are marked 8, 7, 6 and 3 fathoms. Now the fact is, that in

* A copy of the plan given in Admiral Duperrey's 'Atlas of the Voyage of the *Coquille*,' compiled by the lamented M. de Blosseville from information obtained at Sydney from Captain Edwardson and the commanders of some English merchant ships. See also the 'Annales des Voyages,' vol. xxix.—ED. *Journ. Roy. Geogr. Soc*

mid-channel are 35, 25, 22, 18, 15, and a short cable's length from the beach 8 and 9 fathoms. The cutter *Sabrina* at one time rode close to the beach at the top of the harbour, and had 3 fathoms under the stern. The ground is good. The passage between Garden Island and the main is merely a boat passage, and full of rocks. There is not a vestige of a hut in Port Chalky. Preservation Bay, to the southward, is a picturesque spot, full of islands and covered with wood: the beauty of the scenery can hardly be described, but anchoring places are difficult to find, the water is so deep. The soil is good; most garden-roots and seeds grow well, and rye-grass admirably. The plans of Chalky Bay and harbour are good, with the exceptions already mentioned; there are no inhabitants on this part of the island; the ground being covered with wood produces myriads of flies of a very poisonous description; the bite of a mosquito is not to be compared to it for severity and effect; it is a small black fly with a deep blue tinge. I saw no wild animals except rats. The tide here rises about 6 feet, and it is high water at full and change at 11 o'clock."

Jan. 7, 1839.—Sailed for the southward; on the 11th anchored in Perseverance Harbour, Campbell Island, where, by a curious coincidence, they met with Mr. John Biscoe, R.N., in command of the *Emma*, on a sealing voyage. On the 17th again made sail to the south-eastward; on the 19th, in lat. 54°, with the weather calm and fine, the Aurora Australis was very brilliant. On the 23rd, in lat. 59° 16′, long. 173° 20′ E. of Greenwich, the indications of the vicinity of land, as large quantities of seaweed, divers, mutton-birds, etc., were so strong, that, the weather being very thick, the vessels were hove to. On the following day they passed the branch of a tree, but as it cleared neither land nor ice were in sight, and they continued standing to the S.S.E. till the 27th, when in lat. 63° 37′, long. 176° 30′ E., they crossed Captain Bellingshausen's route of the Russian corvette, the *Vostok*, in December, 1820, and here saw their first iceberg. Continuing to the southward, over the very spot where compact ice had forced the Russian navigator to alter his course to the eastward, the vessels, on the 28th, reached their extreme eastern longitude, namely, 178° 13′ E.; and on the following evening, in the parallel of 66° 40′, and long. 177° 50′, the variation observed by azimuth was 28° E. At this time field-ice bounded their southern horizon, and numerous large icebergs were in sight. At sunset on the 30th, in lat. 67° and long. 176°, the variation observed by amplitude was found to be 33° 25′ E. They were now surrounded by icebergs and small drift-ice; the wind during the last week had been constantly from the westward, varying from N.W. to S.W.

At noon, on the 1st of February, the sun broke out and the weather cleared—latitude by observation 68° 45′. At this time no ice was in sight from the mast-head, and they stood to the southward with a fresh breeze till 3 P.M., when they found themselves near the edge of a large

body of packed ice, and were obliged to tack to the northward to avoid it. This, then, was their extreme south point, as they had now reached the parallel of 69° in long. 172° 11′ E., full 220 miles to the southward of the point which Bellingshausen had been able to attain about this meridian: thus adding one proof more that ice in these regions, even in the immediate neighbourhood of land, is very far from stationary.

Feb. 2.—Still embayed in field-ice; the variation this afternoon in lat. 68°, long. 171° 30′, was found to have increased to 36° E. On the 5th observed the water to be much discoloured, and many feathers floating. Saw several whales, sea-leopards, and penguins. Gradually working to the N.W. to clear the ice, against a strong westerly wind, which, contrary to the received opinion, was found to prevail in these high latitudes.

Feb. 6.—This morning commences with light winds and thick weather. At noon, more clear; heard the surf to leeward. About half-past 12 it cleared a little, when we found we were in a deep bay, formed by what evidently appeared to be barrier-ice and close to it. As we proceed west the ice appears to lie more to the northward. Tacked ship to N.N.W.; very little wind from west, and thick fog. The water had been very dirty all day, with a great many feathers. Latitude, noon, by account 67° 37′, long. by account 164° 54′; wind west; thermometer 37°.

Feb. 7.—Begins and continues to the end, light winds and very thick with dirty green-looking water. At noon, lat. 67° 7′, long. 165° 5′; wind west; thermometer 38°.

Feb. 8.—This morning light winds and thick weather. At 2 a.m. heard the roar of surf. At 3 passed a large berg of ice close to us; saw a young seal. No observations this day. At noon, latitude by account 66° 44′, longitude by account 165° 4′; wind N.E.; thermometer 41°.

Feb. 9.—This morning thick fog; passed a great many icebergs and saw a great many penguins. At 8, clear; steering west by compass, got sights for my chronometers, which gave the ship by the Port Chalky rate in longitude, 164° 29′ E.* At 11 a.m. noticed a darkish appearance to the S.W.; observed the latitude to be 66° 37′ S., by meridian altitude; wind north. At noon the sun shone brightly; saw the appearance of land to the S.W., extending from west to about south—ran for it. At 4 made it out distinctly to be land. At 8 p.m. (having run S.W. 22 miles) got within 5 miles of it, when we saw another piece of land of great height, bearing W. by S. At sunset we distinctly made them out to be three separate lands of good size, but the western one the longest. Lay-to all night off the middle island.

* The rate obtained at Port Chalky is used throughout; the London rate would give 1° 40′, or 40 miles distance in this latitude farther east.—Ed. *Journ. Roy. Geogr. Soc.*

Feb. 10.—A 2 a.m. bore up for it, ran through a considerable quantity of drift-ice and got within half a mile, but found it completely ice-bound, with high perpendicular cliffs. I wished to run between the middle and western island, but was compelled to come out to the eastward again, as, from the western island to the eastern one on the west (or rather S.W.) side, the sea was in one firm and solid mass without a passage. The weather at sunrise was very threatening. At 6 it came on thick, since when we have been compelled to stand off. I make the high bluff western points of the middle island to be in latitude 66° 44′ S., longitude 163° 11′ E. A lunar at 2 o'clock agrees with the Port Chalky time. Temperature at noon, 42°; wind east; the weather continuing moderate, but very thick, to the end.

Feb. 11.—Thick. At 1 a.m. had to hoist out a boat to tow the vessel clear of an iceberg which we were close to but could not see, and no wind. At 11 a.m. cleared, and saw the land bearing about W.S.W. and of a tremendous height, I should suppose at least 12,000 feet, and covered with snow. At noon we had a very indifferent observation, which gave the latitude 66° 30′, and it immediately came on thick; wind N.W.; temperature 42°.

Feb. 12.—This morning the weather clears and thickens occasionally. At 2 a.m. saw the land bearing S.S.E. about 10 miles. The west point of the west island bore W.N.W. At 8 land completely ice-bound. At noon, temperature 35°; tacked and worked in shore for harbour or beach. At 4 p.m. abreast of the small island; the eastern island now at a different bearing appeared a large one; latitude by account 66° 22′, longitude 163° 49′ E. At 6 p.m. went on shore in the cutter's boat, at the only place likely to afford a landing; but when we got close with the boat it proved only the drawback of the sea, leaving a beach of 3 or 4 feet at most. Captain Freeman jumped out and got a few stones, but was up to the middle in water. There is no landing or beach on this land; in fact, but for the bare rocks where the icebergs had broken from, we should scarce have known it for land at first, but, as we stood in for it, we plainly perceived smoke arising from the mountain tops. It is evidently volcanic, as the specimens of stone, or cinders, will prove. The cliffs are perpendicular, and what in all probability would have been valleys and beaches are occupied by solid blocks of ice. I could not see a beach or harbour, or anything like one. Returned on board at 7, and got the vessels safely through the drift-ice before dark, and ran along the land.

Feb. 13.—Light winds from the southward and cloudy weather, with much ice around. At 8.30, a fog coming on, took the bearings of the centre of the land S.S.W., distant 16 leagues by the log. Numerous whales and penguins in sight, also a few Cape pigeons and a small white bird, but no albatrosses nor mollymawks. Tried for soundings several times, at the distance of 6, 8 and 10 miles from the land, but got no

bottom. At noon, latitude by account 65° 45′, longitude 164° 51′, wind S., thermometer 37°; altered the course to N.W.

P.M.—Thick fog. Saw many whales and seals, and both icebergs and drift-ice. At midnight, light variable winds and cloudy dark weather.

This was the last time that the land, now appropriately named the Balleny Isles, was seen. The group consists of five islands, three large and two small, the highest of which, named Young * Island, was estimated by Captain Balleny, as well as by his mates, at 12,000 feet above the sea. It rises in a beautiful peak, which may be called Peak Freeman, as being on the island on which the commander of the cutter *Sabrina* landed.

When at the distance of from 8 to 10 miles from the centre island, with the extremes of the land bearing from west round southerly to east by south, the accompanying sketch was made by Mr. John McNab, second mate of the schooner. The outline of the islands is evidently volcanic, and the smoke which arose from the second island to the east, or Buckle Island, and the stones brought away from Young Island by Mr. Freeman, which prove to be scoriæ and basalt, with crystals of olivine, leave no doubt on the subject. These,

THE BALLENY ISLANDS

Discovered 9th February, 1839. West Bluff of Centre Island in lat. 66° 44′ S., long. 163° 11′ E. Land bearing from West to East by South.

* These islands and peaks are named respectively after Messrs. G. F. Young, W. Borradaile, J. W. Buckle, T. Sturge, W. Brown, J. Row, and W. Beale, the spirited merchants who united with Mr. Enderby in sending out this expedition.

then, are, with the exception of that discovered by Bellingshausen in 69° S., the most southerly volcanoes known. The easternmost, or Sturge Island, rises also to a peak, named Brown's Peak, but is not half the height of the former. Immediately off the eastern end of the centre, or Borradaile Island, is a remarkable pinnacle of rock, called Beale Pinnacle, which is described as rising like a tall lighthouse from the waters. The westernmost, or Row Island, is low, and offers no remarkable feature.

Feb. 14.—Continued working to the N.N.W. against a fresh northerly breeze, which on the following day fell light and variable. On the 16th it freshened up from the N.N.E., and at noon this day they had reached as far north as 63° 15′, and were only about 50 miles distant to the southward of the track of Bellingshausen, in 1820, when he first crossed that parallel. We may here notice also that the group of the Balleny isles lie only 145 miles distant, in a S.W. direction, from the point at which the Russian navigators crossed the parallel of 65°, and that, if the weather was very clear (an improbable case in these latitudes), the lofty peak of Young's Island might possibly have been visible on the utmost verge of the south-western horizon from the mast-head of the *Vostok*.

Taking advantage of a fine breeze and a clear sea, the vessels now ran rapidly for 170 miles to the S.W., till the weather becoming foggy obliged them to heave to till the morning of the 18th, when it cleared up, and, finding no ice in sight, they again stood to the southward; latitude at noon, 64° 32′. Captain Balleny remarks that he had observed a clear sea generally between the barriers of ice, and about 2° to the south of it. After a day's variable wind, with snow and sleet, the breeze gradually freshened from the east into a fresh gale, which carried them rapidly to the westward; numerous flocks of mutton-birds, and about thirty whales, were seen, but only one iceberg. On the 22nd, at noon, the latitude observed was 63° 30′, longitude 141° 13′ thermometer 38°, temperature of water 34°. In the afternoon an azimuth, with the ship's head west, gave the variation 17° 52′ E. The two following days continued to the westward against a westerly wind, which on the 25th freshened from the east with snow and sleet; saw immense flocks of birds flying from the N.E. to the S.S.W., many whales and porpoises and a few icebergs. On the 27th, at noon, the observed latitude was 64° 37′, longitude 130° 32′ E., thermometer 35°, temperature of water 34°. An amplitude at sunset, with the ship's head N.W., gave the variation 14° 54′ W; thus, in the difference of 11° of longitude, or a distance of about 250 miles in this parallel, the variation had changed 32° 45′, or nearly three points.

"*March* 1.—With a steady breeze from the S.E. continued standing to the westward—passed several icebergs, and numerous flocks of penguins, petrels, and mutton-birds.

"*March* 2, A.M.—Squally from the S.E., with snow and sleet. At 8 cleared off a little. At noon, latitude observed, 64° 58′, longitude 121° 8′,

thermometer 35°. P.M., strong winds, and showers of snow and sleet; saw a great many birds. At 8, the water becoming smooth all at once, shortened sail and hove-to. Saw land to the southward, the vessel surrounded by drift-ice. At midnight strong breezes with snow.

"*March* 3, A.M.—Found the ice closing and becoming more compact; stood through the drift-ice to the southward. At 8 found ourselves surrounded by icebergs of immense size; to the S.W. the ice was quite fast, with every appearance of land at the back of it, but, the weather coming on thick, were obliged to steer to the northward along the edge of the pack. At noon, latitude by observation 65° 10′, longitude 117° 4′. P.M., fresh breezes from the S.S.E. and clear; numerous icebergs in sight.

"*March* 4.—Moderate and cloudy weather. At 5 hauled to the westward; several icebergs in sight, and a great many birds and whales. At noon, wind increasing, with a heavy sea from the N.W. Latitude by observation 63° 56′; longitude by chronometer, at 4 p.m., 115° 30′. At sunset, found the variation by amplitude, with the ship's head N.E., to be 44° 11′ W. At 9, being surrounded by icebergs, with thick weather and heavy snow squalls, hove the ship to for the night."

The two following days continued standing to the N.W., with variable winds. At sunrise on the morning of the 6th, in latitude 62° 40′, longitude 164°, the variation by amplitude, with the ship's head to the N.N.W., was found to be 42° 21′ W. During the next four days, stormy weather, with snow and sleet from the N.E.; stood to the N.W. whenever the numerous icebergs would allow the vessels to run. At midnight on the 10th, in latitude 61° 20′, the Aurora Australis shone with great splendour. The following day was very fine, with the wind from the N.N.E.; innumerable icebergs in sight. In the afternoon, in latitude 61° 27′, longitude 105° 30′, the variation by azimuth was found to be 34° 30′ W.

During the next few days the vessels slowly made their way to the W.N.W., constantly surrounded by icebergs; saw whales, penguins, several sea-birds and one albatross, the first seen since leaving Campbell Island; this occurred in latitude 61° 30′. May this be the southern limit of the range of this bird, probably the wandering albatross, which was seen by Mr. F. D. Bennett as far north as latitude 38° S. off the coast of Brazil.*

March 13.—Light variable winds from the eastward; surrounded by icebergs; in latitude 61°, longitude 103° 40′, passed ¼ of a mile of an iceberg about 300 feet high, with a block of rock attached to it. . . .

He describes the rock as a block of about 12 feet in height, and about one-third up the berg. It is unnecessary here to make any observation upon this very remarkable fact, as Mr. Charles Darwin has appended a note to these extracts, pointing out the value of such an evidence of the

* Journal, vol. viii. p. 211.—Ed. *Journ. Roy. Geogr. Soc.*

transporting power of ice.* We will, therefore, only add that this iceberg was distant 1400 miles from the nearest *certainly known* land, namely, Enderby's Land, which bore W.S.W. of it. But it is highly probable, from the compact nature of the ice, etc., that land extends between the parallels of 66° and 68° S., in which case the iceberg would not be distant above 300 miles from this supposed land. The appearance of land seen by Captain Balleny on the 3rd of March, as above mentioned, bore from the iceberg E.S.E., distant 450 miles.

On the following day the two vessels crossed the track of our great circumnavigator Cook in 1773, and continuing to the north-westward, they on the 18th, in latitude 58°, longitude 95° 15′, crossed the route of Bellingshausen in 1820. On the 21st, in latitude 55°, the autumnal equinox of these latitudes was rendered brilliant by a magnificent display of the Aurora Australis. Numerous icebergs in sight, with penguins and various sea birds. They now crossed Biscoe's track in April 1831, being the third of the parallel routes, all running to the E.N.E., which occur here within about 5° of latitude; and on the following day encountered a strong gale of wind from the west, with a heavy sea running. In the afternoon of the 24th the gale had much increased. At midnight the cutter *Sabrina* burnt a blue light, distant 1 mile to the S.S.E.; this was answered immediately with another by the schooner, but the sea was running so high that she could not close the cutter.

March 25.—Strong gales and squally weather, the vessel labouring and pitching violently. At daylight, says Captain Balleny's journal, "No signs of the poor cutter being in sight; I trust she may be safe." At 9 a heavy sea broke on board the schooner, staving both boats, and sweeping everything from the decks and laying the vessel on her beam ends; for ten minutes she appeared to be settling in the water, but she gradually righted, and on sounding the well did not appear to be making much water. At noon, blowing a heavy gale from the west, with dark cloudy weather. Latitude by account, 52° 15′; longitude, 94° 15′ E.

On the following day the gale moderated, and the schooner was enabled to stand to the northward, with the wind from the N.W. In latitude 49° they passed a quantity of seaweed, and were surrounded by numerous penguins, divers, and other sea birds. On the 1st April the *Eliza Scott* crossed the parallel of 45°, standing towards the Mozambique channel; and on the 17th September again reached the port of London, just in time to supply another Antarctic expedition, on the eve of its departure from England, with the information they had been enabled to obtain of a newly-discovered group of islands in the South Frozen Ocean.

On looking at the excellent south circumpolar chart, just published

* See Mr. Murchison's 'Silurian System,' p. 541, who notices the great range of icebergs as seen by Captain Vernon Harcourt, R.N., in latitude 50° S. Also Mr. Bennett's voyage in the 'Geographical Journal,' vol. vii. p. 212.

at the Hydrographic Office, it will be seen that this voyage exactly fills up the gap of about 80 degrees of longitude within the parallel of 60°, which, on a former occasion, we pointed out as hitherto not sailed over by any navigator.* About 5 degrees of this navigation was within the polar circle. It were needless to recapitulate here the several voyages which, combined, have effected the circumnavigation of the globe within the parallel of 60°, as a glance at the above-mentioned chart, showing even the track of this voyage, will illustrate it far better than any description; and to that, then, we may refer all those who take an interest in the subject.

It would be impossible to close the simple but apparently faithful narrative of this voyage without adverting to the progress made in discovery in the Southern Seas through the spirited exertions of Mr. Charles Enderby, and other British merchants, so honourable to the commercial enterprise of our country. Graham Land, Enderby Land, Kemp Land, and now the Balleny Isles, are all discoveries made by the ships belonging to this disinterested and praiseworthy owner. The results of this voyage must tend to keep alive the supposition of the existence of either a great southern land or a vast mass of islands, whose northern limits would seem to range between the 67th and 69th parallels, a part of which we trust, ere long, to see laid down in our charts, and not improbably rendered subservient to the interests of science, if not to the prosperity of our fisheries. Still less can we refrain from adverting to the expedition of the *Erebus* and *Terror*, commanded by Captain James Ross, which has recently left our shores, liberally fitted out by Her Majesty's government in the most complete manner, for scientific purposes, of any ships that ever sailed from Europe; and it is gratifying to know that the voyage of the *Eliza Scott* cannot but prove useful towards the success of the greater expedition, inasmuch as the Balleny Isles are situated exactly on the eastern verge of the circle traced by Captain James Ross on his chart, as the limit within which he hoped to find the southern magnetic pole; and thus their discovery will almost insure him a spot for planting his instruments at one of the places most desirable for making observations on magnetic dip, variation, and intensity.

And, although this latter expedition is mainly fitted out with the object of deciding the great problem of terrestrial magnetism in the southern hemisphere, and that its attention will be chiefly directed to this branch of physical geography, we cannot but hope that it may also do much in the cause of Antarctic discovery, and conclude with the earnest wish that the well-known zeal and ability of the gallant commander may be crowned with success, and that he may safely return to his country and his friends to receive the well-merited reward of his toils in the applause and esteem of all civilised nations.

* Letter to the President of the Royal Geographical Society on Antarctic Discovery, 1836, p. 12.

NOTE ON A ROCK SEEN ON AN ICEBERG IN 61° S. LAT.

BY CHARLES DARWIN, ESQ.

Having been informed by Mr. Enderby that a block of rock, embedded in ice, had been seen during the voyage of the schooner *Eliza Scott* in the Antarctic Seas, I procured through his means an interview with Mr. Macnab, one of the mates of the vessel, and I learnt from him the following facts: On the 13th of March, when in latitude 61° S., and longitude 103° 40′ E., a black spot was seen on a distant iceberg, which, when the vessel had run within a quarter of a mile of it, was clearly perceived to be an irregularly-shaped but angular fragment of dark-coloured rock. It was embedded in a perpendicular face of ice, at least 20 feet above the level of the sea. That part which was visible, Mr. Macnab estimated at about 12 feet in height, and from 5 to 6 in width; the remainder (and from the dark colour of the surrounding ice, probably the greater part) of the stone was concealed. He made a rough sketch of it at the time. The iceberg which carried this fragment was between 250 and 300 feet high.

Mr. Macnab informs me that on one other occasion (about a week afterwards) he saw on the summit of a low, flat iceberg a black mass, which he thinks, but will not positively assert, was a fragment of rock. He has repeatedly seen, at considerable heights on the bergs, both reddish-brown and blackish-brown ice. Mr. Macnab attributes this discolouration to the continued washing of the sea; and it seems probable that decayed ice, owing to its porous texture, would filter every impurity from the waves which broke over it.

Every fact on the transportation of fragments of rock by ice is of importance, as throwing light on the problem of "erratic boulders," which has so long perplexed geologists; and the case first described possesses in some respects peculiar interest. The part of the ocean where the iceberg was seen is 450 miles distant from *Sabrina* land (if such land exists), and 1400 miles from any certainly known land. The tract of sea, however, due south, has not been explored; but assuming that land, if it existed there, would have been seen at some leagues' distance from a vessel, and considering the southerly course which the schooner *Eliza Scott* pursued immediately prior to meeting with the iceberg, and that of Cook in the year 1773, it is exceedingly improbable that any land will hereafter be discovered within 100 miles of this spot. The fragment of rock must, therefore, have travelled at least thus far from its parent source; and, from being deeply imbedded, it probably sailed many miles farther on before it was dropped from the iceberg in the depths of the sea, or was stranded on some distant shore. In my journal, during the

voyage of H.M.S. *Beagle*, I have stated, on the authority of Captain Biscoe, that, during his several cruises in the Antarctic seas, he never once saw a piece of rock in the ice. An iceberg, however, with a considerable block lying on it, was met with to the east of South Shetland by Mr. Sorrell (the former boatswain of the *Beagle*) when in a sealing vessel. The case, therefore, here recorded is the second; but it is in many respects much the most remarkable one.* Almost every voyager in the Southern Ocean has described the extraordinary number of icebergs, their vast dimensions, and the low latitudes to which they are drifted. Horsburgh † has reported the case of several which were seen by a ship in her passage from India, in latitude 35° 55′ S. If, then, but one iceberg in a thousand, or in ten thousand, transports its fragment, the bottom of the Antarctic Sea, and the shores of its islands,‡ must already be scattered with masses of foreign rock—the counterpart of the "erratic boulders" of the northern hemisphere.

* See p. 357, l. 6.

† 'Philosophical Transactions,' 1830, p. 117.

‡ M. Cordier, in his instructions ('L'Institut,' 1837, p. 283) for the voyage of the *Astrolabe* and *Zélée*, says that the shores of South Shetland were found, by the naturalist of an American expedition in 1830, covered with great erratic boulders of granite, which were supposed to have been brought there by ice. It is highly desirable that this fact should be inquired into if any opportunity should hereafter occur.

EXTRACT FROM THE LOG* OF THE SCHOONER 'ELIZA SCOTT,' CAPTAIN JOHN BALLENY, WHILE S. OF 55° S. LATITUDE, 1839, KEPT BY JOHN MCNAB, SECOND MATE.

Monday, Jan. 21, 1839.—Steady breezes and cloudy weather; passed a small quantity of kelp, and saw several birds. At 8 a.m., longitude by chronometer, 172° 0′ 15″ E.; spoke the cutter. Latitude at noon, 55° 55′ S.; longitude by account, 172° 52′ E.; squally, with small rain. At 4 p.m., longitude by chronometer, 172° 19′ E. At 8, in first reef mainsail. Midnight, squally, with a head sea.

Tuesday, Jan. 22.—Hard squalls, with a heavy head sea, and thick, hazy weather. Longitude by account, 172° 39′ E.; latitude by observation, 57° 59′ S.; cutter half a mile S.S.E., bearing, carrying all requisite sails, etc.; thick, hazy weather, with a heavy swell from the east; passed a hank, supposed to have belonged, by the appearance of it, to some vessel's jib or staysail.

Wednesday, Jan. 23.—Thick, hazy weather, with small rain; saw several divers and a quantity of kelp. Latitude by account, 59° 16′ S.; longitude by account, 174° 43′ E. At noon, ditto weather. No observation; cutter in our wake within hail; weather thick and foggy; saw flocks of mutton-birds, and a great quantity of kelp. At 6 p.m., it clearing off a little, the man that was looking out forward reported land to the south, but it being so thick it could not be made out. Double-reefed the sails and brought the vessel to the wind for the night, but a gale of wind coming on we were forced to lay to, in hopes that it would be clear in the morning; cutter within hail.

Thursday, Jan. 24.—Still blowing hard, with thick fog; took in third reef mainsail and reefed the jib. At 4, still thick and foggy; Kept away; no birds or kelp to be seen. No observation. Weather more moderate, but still thick; out reefs and made all sail requisite. Latitude by account, 60° 33′ S.; longitude by account, 175° 53′ E. At 10, it coming on a thick fog, spoke the cutter and hove to.

Friday, Jan. 25.—Moderate and foggy weather. At 7 a.m., it clearing off, made sail. Longitude by chronometer, 176° 37′ 15″ E., at 8. Noon, moderate and hazy. Set the squaresail. Latitude by observation, 61° 45′ S.; thick, with small rain.

Saturday, Jan. 26.—Light winds and foggy weather. Saw several divers, whales, and some kelp. Latitude by account, 62° 28′ S.; longi-

* In the possession of the Royal Geographical Society.

tude by account, 177° 58′ 0″ E. Mate took sick, bled and blistered him, etc. Light airs and calms, with thick weather and rain. At 6, foggy, with light winds; passed several pieces of kelp, a sea leopard and some divers. Midnight, ditto wind and weather. Several black whales playing round the ship.

Sunday, Jan. 27.—A.M. Breeze sprung up from the south-west, with clear weather. Saw some more kelp and divers. At 4, steady breeze, with cloudy weather. At 6, increasing breeze, and the sea getting up. At 8, longitude by chronometer, 177° 55′ 15″ E. At 9, saw the ice. At noon, islands of ice in sight. Latitude by observation, 63° 35′ S. Squally, with showers of snow and sleet. Mate convalescent. Midnight, strong winds, with a heavy sea on from the south. Many icebergs in sight; shortened sail. Cutter in company.

Monday, Jan. 28.—Strong winds with a heavy sea, with frequent showers of snow, sleet, etc. At daylight, found ourselves entirely surrounded by icebergs. Hauled to the wind under double-reefed sails, and steered otherwise as requisite to clear the ice. At 8, longitude by chronometer, 170° 10′ 0″ E. At noon, hazy weather, amid much ice. Spoke the cutter. Latitude, observation, 65° 35′ S. P.M., wind inclinable from the southward with fine, clear weather. Saw some ice on the lee beam. At 4, longitude by chronometer, 179° 48′ 0″ E.; variation from azimuth, 27° 57′ E. At 6, fair weather, with less sea. Out all reefs. At 8 it fell calm. Vessel rolling violently in the trough of the sea at midnight. Light breeze sprung up from the N.W. Crowded all sail to give easement to the schooner.

Tuesday, Jan. 29.—Increasing breeze and hazy weather. At 4 a.m., came on to snow and kept on until noon with hazy weather. Took in first reef mainsail. At noon, wind worked round to the W.S.W., with clear weather; much ice in sight. Cutter in company. Longitude by account, 179° 44′ 0″ E.; latitude by observation, 66° 31′ S. At 2 p.m., wind flew round to the E.S.E. with squalls and snow; much ice in sight. At 4 p.m., longitude by chronometer, 179° 9′ 15″ E. In the evening, saw a vast body of field-ice to the south. Variation by amplitude, 33° 25′ E. At midnight, light winds and clear weather. Many whales in sight, some sea leopards, and much ice.

Wednesday, Jan. 30.—A.M., light winds and clear weather. Longitude by account, 178° 7′ 15″ E. At noon, ditto wind, latitude by observation, 66° 52′ S. Cutter in company. Ice and whales in all directions. P.M., thick weather, with snow and sleet. In first reef mainsail and E.S. sail. Midnight, ditto weather with much ice and snow.

Thursday, Jan. 31.—Still foggy, with snow and sleet, passing much rotten ice. At 8 a.m., ditto weather. Cutter in company. Latitude by observation, 67° 13′ S.; longitude by account, 176° 14′ 15″ E. Thick fog, with snow. The vessels going through a vast quantity of scattered

rotten ice; it clearing off a little, saw several icebergs. At midnight, saw several penguins, petrels and other birds.

Friday, Feb. 1.—A.M., increasing breeze and cloudy. No ice to be seen anywhere, but the sea remarkably smooth for so much wind. Supposed ourselves under the lee of a body of field-ice. At 8, steady breezes with clear weather, and a clear sea. Longitude by chronometer, 174° 6′ E; latitude by observation, at noon, 68° 45′ S. Ditto weather. Spoke the cutter. P.M., strong winds and cloudy. At 3, saw a large extent of packed ice, to the S. and E. as far as the eye could reach. Tacked; cutter in company. Strong breezes, with a heavy head sea on. Midnight, more moderate.

Saturday, Feb. 2.—A.M., moderate and cloudy, with less sea. At 8, longitude by chronometer, 173° 39′ 15″ E. At 9, tacked; no ice in sight. At noon, ditto weather. Latitude observation, 68° 11′ S. Cutter in company. At 4 p.m., variation by azimuth, 36° E. At 6, saw a large extent of field and packed ice, reaching from W. by N. to E.S.E. Tacked. Cloudy weather. Midnight, squally, with snow and sleet.

Sunday, Feb. 3.—A.M., squally, with snow and sleet. At 2, passed a large iceberg. At 8, longitude by chronometer, 171° 58′ E. At noon, moderate and cloudy. Several icebergs in sight. Spoke the cutter, and out all reefs. Latitude by observation, 67° 34′ S. P.M., strong breezes and cloudy, with a heavy head sea. At 7, longitude by chronometer, 172° 13′ 45″ E. At midnight, ditto weather. Several icebergs in sight. Tacked.

Monday, Feb. 4.—Strong breezes and cloudy, much ice in sight. At 8 a.m., longitude by chronometer, 170° 51′ E. Latitude by observation, 67° 24′ S., moderate and cloudy weather. At 10, light airs, with thick, foggy weather, and showers of sleet and snow at intervals.

Tuesday Feb. 5.—A.M., still foggy, with light winds and smooth water. At noon, ditto weather. Latitude by observation, 67° 40′ S. Longitude by account, 168° 18′ E. Light winds and smooth water, with thick, hazy weather; out all reefs, and made all possible sail. Midnight, still thick fog. Saw several whales and sea leopards playing round the vessels, and some dozen or two king penguins.

Wednesday, Feb. 6.—Light winds and variable from the south and west, with thick fog and smooth water. Saw some king penguins and leopards and whales. At 11 a.m. passed an iceberg and heard the rustling of the ice under our lee; it being a little wind, became a little concerned about it. At noon it cleared off a little, and we saw the ice distinctly, in a horseshoe form, completely round the vessels. It thickening again directly, we tacked with the view, if possible, to lead off. At 1 p.m. a light air sprung up from the west, and we steered N.N.W. to haul off. The current setting to the S.E. Latitude by account, 67° 36′ S.; longitude by account, 166° 34′ E.; latitude by single altitude, 67° 47′ S. Midnight, light winds and thick fog.

Thursday, Feb. 7.—Light winds, with smooth water and a thick fog. At 8 a.m., tried the current, and found it setting W. by S. by comp., half a mile an hour. Birds very scarce, penguins and whales about in plenty. Latitude by account, 67° 7′ S.; longitude by account, 166° 43′ E. At noon, thick fog, with smooth water and small rain. Lowered the mainsail down and repaired it. At 6 p.m., heavy swell from N.W. Midnight, ditto weather.

Friday, Feb. 8.—Thick fog. Passing much ice. Several penguins in sight and one sea leopard. At 8, set squaresail. At noon, took in the squaresail; thick fog; much ice. No observations. Latitude by account, 66° 44′ S.; longitude by account, 166° 44′ E. At 8 p.m., reefed the mainsail. At 9, took in the foresail. At 10, hove to; thick fog.

Saturday, Feb. 9.—Thick fog, with much ice. Lying to. At 4 a.m., saw a young seal close alongside. The water very much discoloured, and whales in shoals. At 8, longitude by chronometer, 166° 3′ E. At 11.30, saw what we took to be land on our lee bow. Spoke the cutter. Set the squaresail and steered for it. Latitude by observation, 66° 37′ S. At 4 p.m., saw the land distinctly bearing about S.W. Two large islands and several smaller ones. At 6, saw a third one to the westward. At 8, hove to. Fair weather and clear, with smooth water. Whales and penguins in plenty. Saw two seals alongside.

Sunday, Feb. 10.—At 2 a.m., steered for the land. At 4, about half a mile distant from the middle island of the three. Saw no appearance of any harbour or beach, it being completely icebound. Tacked and stood off to the N.E. Thick fog, with heavy rain. No land in sight at 10 a.m. At noon, ditto weather. No observations. Latitude by account, 66° 24′ S.; longitude by account, 164° 49′, Lond. Rate; 163° 11′ 15″, Chalky R. At 4 p.m., tacked. At 8, calm, with thick fog. Saw some seals, whales and penguins. At midnight, ditto weather.

Monday, Feb. 11.—At 1 a.m., got the boats out and towed till 3 to clear the ice. At 4, got the boats in; light airs from the N.E. At 6, calm. At 11, saw the land to the S.W. Tacked for it; distant about 12 leagues. At noon, latitude by single altitude, 66° 25′ S; by an imperfect meridian altitude, 66° 30′ S. Spoke the cutter. Afternoon closed in with light winds and thick fog. Whales and penguins in sight. Longitude by account, 164° 37′ E. Got the best bower-anchor up, and the cable bent. At 8 p.m., it fell calm, with fog. A heavy swell from the N.E. setting the vessel to the S.W., half a knot an hour.

Tuesday, Feb. 12.—Set half a mile an hour to the S.W. by the N.E. swell. At 2 a.m., weather cleared up; saw the land. At 3, light airs from the eastward. At 8, small island S.S.E., distant ten miles; west point of the west island bearing W.N.W. The land completely icebound. At noon, tacked and worked up; short tacks towards the land to see for harbours or beaches. Cutter in shore. At 4 p.m., small island abreast, quarter mile distant. Spoke the cutter, and saw another

large island to the S.S.E. Latitude by account, 66° 22′ S.; longitude by account, 163° 49′ E. At 7 p.m., ship's place the same as at noon. The two captains went on shore, and brought some stones off. Made sail, and steered as requisite to clear the ice with which this land is bound. At midnight, light winds and clear weather.

Wednesday, Feb. 13.—A.M., light winds and cloudy, with much ice. Steered as requisite. At 8.30, it coming on foggy, took the bearing of the body of the land S.S.W., distant by the log sixteen leagues. Saw neither albatross nor mollymawk here, only a few Cape pigeons, and a white bird, rather smaller, and only a few of them. Saw several penguins, and whales very numerous. Tried for soundings several times, at six, eight and ten miles from the middle island, but got no ground with 200 fathoms. Made out five islands, three large ones and two small ones. Land very high. At noon, thick fog, with light wind; jibed and steered to the N.W. Put the anchor in the hold, and the chain in the locker. Latitude by account, 65° 45′ S.; longitude by account, 164° 51′ E.; variation, 3 points E. P.M., thick fog. Saw several whales, seals, and drift-ice. At 4, it clearing up, saw the appearance of land to the west, and steered for it. Came on thick again; cleared off at 8, but saw no land, but plenty of icebergs. At midnight, light winds and dark, cloudy weather.

Thursday, Feb. 14. A.M., breeze freshening, with rain. At 2, wind scanting, took in the squaresail, and set the fore-staysail. At 4, heavy rain. At 6, wind increasing, with snow and sleet. At noon, ditto, ditto, took in two reefs of the mainsail and fore-staysail. Latitude by account, 64° 21′ S.; longitude by account, 163° 35′ E. At 2 p.m., wind flew round to the westward, with less sea. Cutter in company. At 4, wind and sea gradually dying away. Out all reefs. At 8, light winds and cloudy weather. At midnight, calms and flaws of wind and rain.

Friday, Feb. 15.—At 3 a.m., out sweeps to tow her clear of a large iceberg. At 4, light air sprung up from W.S.W., which enabled us to clear it. Thick fog, with heavy rain and N.W. swell. At noon, ditto weather. Employed breaking out provisions, filling salt water, etc. Latitude by account, 63° 54′ S.; longitude by account, 162° 56′ E. Light winds, with fog. At midnight, tacked.

Saturday, Feb. 16.—A.M., steady breezes and cloudy. At 8, longitude by chronometer, 160° 56′ 30″ E., supposing the latitude by account to be correct. At noon, dark, cloudy weather, with small rain this twelve hours, and heavy N.W. swell. Saw two divers, a flock of birds, could not make out what sort; several whales. Spoke the cutter. No observation. Latitude by account, 63° 15′ S. Steady breezes and cloudy weather. Passed several icebergs. At 8 p.m. took in the squaresail. Thick fog. Midnight, light winds and fog.

Sunday, Feb. 17.—Light winds and cloudy. At 2 a.m. set the squaresail. Several icebergs in sight. At noon, cloudy, with heavy swell

from the N.W. Spoke the cutter. Latitude by an imperfect meridian altitude, 64° 17′ S.; by account, 63° 40′ S. I suppose the variation is less here, but have had no opportunity of trying lately. Strong breezes. with fog. Longitude by account, 159° 25′ E. At 11 p.m., strong gales, with heavy sea; hove to.

Monday, Feb. 18.—A.M., laying to. At 8, more moderate, with less sea. Made sail. At noon, ditto weather. Latitude by observation, 64° 32′ S.; longitude by account, 155° 41′ E. Light winds and variable. Out all reefs. Calm, with fog and rain.

Tuesday, Feb. 19.—Light airs and calms, with a heavy swell and cloudy weather. At 9 a.m., longitude by chronometer, 152° 55′ E.; latitude by observation, 64° 24′ S. P.M., ditto weather, with sleet. At midnight, increasing breeze, with snow and sleet.

Wednesday, Feb. 20.—A.M., strong winds and cloudy, with snow and sleet. At noon, ditto weather. Latitude by account, 64° 15′ S. Longitude by account, 148° 54′ E. Repaired the mainsail. At 4 p.m. saw several flocks of mutton-birds and a school of whales. At 8, double-reefed mainsail and fore-staysail. Midnight, moderate and clear.

Thursday, Feb. 21.—Steady breezes. Saw an iceberg to windward. Out reefs, and set the squaresail. At 8 a.m. repaired the mainsail. At noon, clear weather. Latitude by observation, 64° 6′ S.; longitude by account, 144° 38′ E. Light winds and cloudy weather. At 8 p.m., squally, with snow and sleet. Double-reefed the sails. At midnight, ditto weather.

Friday, Feb. 22.—A.M., squally, with snow and sleet. At daylight, saw three icebergs. At 8, tacked, and out all reefs. At noon, light winds and clear. Latitude by observation, 63° 30′ S.; longitude by account, 143° 25′ E. Tacked. Variation by azimuth, 17° 52′ E. At 4 p.m. tacked. Longitude by chronometer, L.R., 142° 53′ E. Employed repairing the foresail. Midnight, light winds, with showers of sleet and snow.

Saturday, Feb. 23.—Calms, with snow and sleet. At 4 a.m., breeze sprung up from the south, made sail. At 8, longitude by chronometer, 141° 34′ 30″ E. At noon, fair weather; passed an iceberg; saw several penguins, divers and whales. Employed in repairing the second foresail. Latitude observation, at noon, 63° 36′ S.; longitude by chronometer, at 4 p.m., 140° 55′ 15″ E. Unbent the storm-trysail, and bent the second foresail. At 9, dark and cloudy with rain; tacked and reefed the mainsail.

Sunday, Feb. 24.—A.M., increasing breeze, with snow and sleet. Spoke the cutter. At daylight saw several divers, penguins, mutton-birds, and porpoises. Set the squaresail. At 11, split the squaresail; took it in. At noon, ditto weather, with a heavy sea on. Latitude by an imperfect altitude, 63° 46′ S; longitude by account, 139° 17′ E. Strong winds, with snow and sleet. During this afternoon saw several

flocks of mutton-birds and several whales. Thick, foggy weather. Midnight, light winds with rain.

Monday, Feb. 25.—A.M., light winds and cloudy; strong winds with snow. At noon, double-reefed mainsail. Latitude by account, 63° 40′ S.; longitude by account, 134° 50′ E. P.M., moderate, with snow. Saw several flocks of birds, going from the N.E. to the S.S.W.; saw a great many whales and a few penguins. At midnight, squalls, with snow and sleet, and a heavy sea running.

Tuesday, Feb. 26.—At 1 a.m. shortened sail for cutter. At 2, filled and made sail. At 4, strong breeze, with snow and sleet. Split the foresail; took it in, repaired it, reefed it and set it. At 8 it cleared off a little to the N.E. Thought we saw the land; tacked and stood for it. At 11.30, made it out to be fog hanging over some iceberg. At noon, ditto weather. Latitude, observation, 64° 40′ S.; longitude by account, 131° 35′ E. Thick fog, with snow and sleet. At 2 p.m. passed an iceberg. At 4 it cleared off a little; saw several icebergs; out all reefs. At 7, tacked to clear the iceberg. Thick, hazy weather, with little wind and a heavy sea. At midnight, light winds and variable, with hard frost and less sea; a great many penguins.

Wednesday, Feb. 27.—A.M., light winds with hard frost; several icebergs in sight. At 4, tacked; dark, cloudy weather. At 8, longitude by chronometer, 132° 21′ 45″ E; latitude, 64° 38′ S. At noon, snow-storm, with thick weather. No observations; latitude by account, 64° 37′ S. At 1 p.m., wind flew round to the N.W.; took in the squaresail, and hauled to the wind. At 4, light winds and variable, with cloudy weather; several icebergs in sight, and penguins. At 7, strong winds, in two reefs, mainsail and fore-staysail. Midnight, snowstorms and fog; took in fore-staysail and foresail. Variation by an amplitude at ☉ set, 14° 54′ W.

Thursday, Feb. 28.—A.M., in third reef mainsail and reef foresail. At 2, hove to under three reefed mainsail and two reefed fore-staysail. At 4, set the jib and kept away; still blowing hard, with showers of snow and sleet, and a heavy sea. At noon, more moderate and clear; passed a large iceberg. Latitude by observation, 64° 19′ S.; longitude by account, 128° 50′ E. P.M., out one reef mainsail, foresail, and set the squaresail, jibed. At 4, longitude by chronometer, 129° 25′ 15″ E. At 6, increasing breeze, with dark, cloudy weather; many flocks of mutton-birds and petrels. Midnight, steady breeze and cloudy, with a heavy sea on; passed a large iceberg.

Friday, March 1.—A.M., steady breezes and cloudy. At 6, out all reefs. Noon, dark, cloudy weather. Several icebergs in sight, and a great many birds. Latitude by account, 64° 5′ S.; longitude by account, 124° 47′ E. P.M., light winds and cloudy. At 6, finished repairing the squaresail and set it. Midnight, increasing breeze, with cloudy weather and frost.

Saturday, March 2.—A.M., squally, with snow and variable winds. At 4, heavy showers of snow, etc. At 8, cleared off a little. Longitude by chronometer, 122° 18′ E. At noon, cloudy weather. Latitude by observation, 65° S.; longitude by account, 122° 44′ E. Strong winds and thick weather, with showers of snow and sleet. At 6 p.m. close-reefed the sails. Saw a great many birds. At 8, the water becoming smooth all at once, took in the squaresail and hove to. Saw the land to the south. Much small ice about the vessels; the supposed land not more than one mile to windward. Midnight, strong winds, with snow.

Sunday, March 3.—At 4 a.m. found the ice so close, and getting more compact. Tacked in hopes of getting between it and the land, but the weather is so thick that we should hit it before we saw it again. At 8 it cleared off a little. Saw the appearance of land to the south, but there being so much ice between the vessels and it, we were glad to get out again safe. The weather dark and cloudy, and sometimes foggy, with smooth water. At 11, still saw the appearance of land to the west, but it coming on thick, and the vessels surrounded with ice, we steered as requisite to gain the open sea. At noon, made sail. At 9, longitude by chronometer, 118° 45′ 30″ E.; latitude, 65° 16′ S. Latitude at noon, by observation, 65° 10′ S. P.M., strong breezes and clear. Steering along the edge of the pack ice; many icebergs in sight. Midnight, moderate and cloudy.

Monday, March 4.—A.M., moderate and cloudy. At 5, hauled to the westward. At 8, out all reefs. Many icebergs in sight, and a great many birds and whales. At noon, increasing breeze, and cloudy with a heavy sea from the N.W. Latitude, observation, 63° 56′ S.; longitude by account, 116° 11′ E. Took one reef in mainsail and fore-staysail. At 4, in second reef, ditto, ditto; longitude by chronometer, 115° 30′ 15″ E.; latitude, 63° 44′ S. P.M., strong winds and cloudy weather, with a heavy sea running. Many icebergs. At 9, surrounded by icebergs. Thick weather, and the snow squalls so severe that we hove to for the night. Midnight, ditto weather. At sunset found the variation to be 44° 11′ W.

Tuesday, March 5.—A.M., strong gales with a heavy sea; laying to; many icebergs in sight. At 7, wore and set jib and foresail. Close reefed. At 8, longitude by chronometer, 114° 45′ 38″ E.; latitude, 63° 07′ S. At noon, more moderate. Out one reef mainsail and fore-staysail; latitude by observation, 63° 1′ S. P.M., squally, with snow-showers. Saw a great many birds; many icebergs in sight. At midnight, steady breezes with snow and sleet.

Wednesday, March 6.—A.M., steady breezes and clear, with a heavy sea, and many icebergs in sight. Variation by an amplitude, 42° 21′ W. At 9, longitude by chronometer, 113° 34′ 15″, E.; latitude, 62° 26′; latitude by observation, 62° 20′ S. At noon took in one reef fore-staysail, foresail and mainsail. At 4 p.m., in second reef mainsail.

Longitude by chronometer, 112° 52′ 15″ E.; latitude, 62° 11′ S. At midnight, moderate and cloudy; out all reefs.

Thursday, March 7.—A.M., cloudy with snow; snow and sleet; many icebergs; dark and cloudy, with a heavy sea; no observation. Latitude by account, 61° 30′ S.; longitude by account, 111° 43′ E. At 1 p.m. took in two reefs; at 4 p.m., strong gales; hove to under balance; reefed mainsail and two reef forestaysail. At midnight wore ship.

Friday, March 8.—Laying to; many icebergs. At 6 a.m., out two reefs mainsail, one reef foresail and fore-staysail, and set the jib. At noon, ditto weather. Latitude by observation, 61° 39′ S; longitude by account, 111° 27′ E. Got the storm-trysail up and bent to the gaff, ready to set as occasion may require, the foresail and mainsail being very bad, and not trustworthy in a gale of wind. At 8 p.m., tacked; passed several icebergs. At midnight, thick and hazy, with sleet and rain.

Saturday, March 9.—A.M., increasing breeze and thick, with rain and a heavy cross sea; shipping much water. A great many icebergs. At noon, ditto weather; in one reef foresail and two reef forestaysail. *Sabrina* in company. Latitude by account, 61° 01′ S.; longitude by account, 108° 30′ E. Thick, foggy weather, with rain, sleet, and many icebergs. At 8 p.m., strong winds, with snow and sleet; close reefed and hove to till daylight. Midnight, laying to.

Sunday, March 10.—A.M. at 3, steady breezes and clear; set double reefed sails. At 6, out all reefs. At 8, longitude by chronometer, 107° 40′ E.; latitude, 61° 13′. Many icebergs in sight. At noon, latitude by observation, 61° 13′ S. P.M., dark and squally, with snow. At 4, in two reefs fore-staysail and mainsail and foresail. At 6, unbent the foresail and bent the storm-trysail forward. Hard squalls, with snow and sleet, and a heavy swell from the northward. At midnight, moderate and clear; the Aurora Borealis in great splendour during the night.

Monday, March 11.—A.M., fair weather and clear. At daylight, saw a great many icebergs. At 8, longitude by chronometer, 105° 55′ 50″ E.; latitude, 61° 27′. Got the old mainsail up and condemned it, and took all the good canvas out to repair the second foresail with; got all the sails up and well aired them. At noon, pleasant weather; innumerable icebergs in sight. Latitude by observation, 61° 27′ S. At 4 p.m., longitude by chronometer, 105° 44′ E.; variation by azimuth, 34° 30′ W. Unbent the storm-trysail and bent the new foresail. At midnight, squally, with snow and sleet; in one reef each sail. Many icebergs.

Tuesday, March 12.—A.M., cloudy, with showers of snow and sleet; many icebergs. At 8, longitude by chronometer, 104° 41′ 45″ E.; latitude, 61° 45′ S. At noon, ditto weather. No observation. Latitude by account, 91° 41′ S. P.M., dark and cloudy weather. Icebergs innumerable. Saw some penguins, whales, and several sea birds; saw one albatross, the first since we left Campbell's Island. At 4, longitude by chrronometer,

104° 19′ 30″ E.; latitude, 61° 34′ S. At 10, light winds; out all reefs to clear the ice. At midnight, ditto, ditto.

Wednesday, March 13.—A.M., light winds and variable, with showers of snow and sleet, and hard frost during the night. At 8, cloudy. Vessels surrounded by icebergs. Saw a great number of mutton-birds, some penguins and whales. Passed one iceberg, with a piece of rock attached to it. This morning Captain Freeman came on board and brought the boy Smith with him, and took the boy Juggins on board the cutter. Longitude by chronometer, 103° 49′ 45″ E.; latitude, 61° 15′ S. Noon, ditto weather. Latitude by observation, 61° 12′ S. P.M., begins with light winds and clear weather. Ship surrounded with icebergs. At 4, breeze freshening, with snow and threatening appearance; double-reefed mainsail. At 6, snow, sleet, etc. Longitude by observation, 103° 49′ 45″ E.; latitude, 61° 15′ S. At 10, steady breeze, with more favourable appearance. Midnight, ditto weather; passed many icebergs.

Thursday, March 14.—A.M. Begins with light winds and cloudy weather, with smooth sea. At 4, ditto wind and weather; passed several icebergs. At 8, ditto weather, with light winds. Longitude by observation, 103° 11′ 15″ E.; latitude, 60° 40′ S. Noon, light wind, with cloudy weather and small snow. Latitude by indifferent observation, 60° 37′. P.M., steady breeze and cloudy weather. At noon, ditto weather, wind inclining from the southward. At 5, wind hauled round to S.W. Jibed ship; set squaresail; double-reefed mainsail and fore-staysail. At 7, wind westered; in squaresail and set fore-staysail. At 8, light wind and cloudy; icebergs. At midnight, light airs and cloudy weather.

Friday, March 15.—A.M., daylight; light winds and cloudy weather. Out all reefs. Innumerable icebergs round the ship; many not less than 300 feet in height above the level of the sea. At 8, light winds and variable; all necessary sail set. Longitude by observation, 99° 29′ 15″ E.; latitude by account, 59° 35′ S. Noon, light breeze and clear weather. Latitude by observation, 59° 30′ S. P.M., light airs and clear weather. Employed refilling water cask in the hold, and sundry requisite jobs. At 4, light airs inclining to calms. At 8, light airs and variable, with clear weather. Midnight, light airs inclining to calms. Aurora Borealis very vivid all this night.

Saturday, March 16.—A.M., calms, with clear, bright weather and smooth water; Aurora Borealis very distinct. Lowered the mainsail down and also the fore-staysail. At 4, ditto wind and weather. Repairing the mainsail. At 8 a.m., longitude by observation, 95° 50′ 15″ E.; latitude by observation, 59° 19′ at 4 p.m. At 8.30, breeze sprung up from the S.W., set the squaresail; took in the foresail. Latitude by observation, 59° 14′ S. At noon, fresh breeze and clear. Many icebergs in sight; spoke the cutter. P.M., breeze freshening, with clear weather. Finished repairs of mainsail and set it single reefed. At 7, took in the squaresail. At 10, shortened sail and hauled by the wind. At 10,

Smith, the fisherman, being at the tiller, and it getting dark and all hands busy shortening sail, the captain conned the vessel, intending to hail the cutter, when giving directions to Smith to starboard and port the helm as required, desired him to answer that he (the captain) might know whether he heard him or not, when Smith became exceedingly insolent to the captain, and at last let go the tiller, hove the tiller-rope in the captain's face, and swore that he would not take the tiller any more while he was in the vessel, and was so abuseful that the captain was obliged to take him by the neck and push him forward. (The last three words were written many days after the others.)

Sunday, March 17.—At 4 a.m. set double-reefed sails; kept away. At 8, steady breezes and clear. Many icebergs. Out one reef foresail and fore-staysail. At noon, sent for Smith to know if he was going to come on deck to his duty, when he refused absolutely. At noon, ditto weather. Latitude by observation, 58° 24′ S.; longitude by account, 95° 50′ E. P.M., strong breezes and cloudy weather; double-reefed the sails. At 9, took in the mainsail and jib, and hove-to for the night. At midnight, light airs and cloudy.

Monday, March 18.—A.M., light winds and cloudy. At 4, out all reefs and made sail. At 8, longitude by chronometer, 95° 4′ E.; latitude 57° 38′ S. At noon, latitude by observation, 57° 27′ S. Light winds and cloudy, with many icebergs in sight and some whales. P.M., calm. Broke out the hold for provisions, and heard that Smith was not well. At 6, light winds and variable, with dark, cloudy weather. Many icebergs in sight. Midnight, ditto, ditto.

Tuesday, March 19.—A.M., calm. At 2, light airs and cloudy. At 8, squally, with much ice. At noon, dark, hazy weather, with threatening appearance. Took in two reefs. Latitude by observation, 56° 45′ S.; longitude by account, 94° 02′ E. P.M. At 4, longitude by chronometer, 94° 55′ 15″ E.; latitude, 56° 42′. Squally, with snow and sleet. In two reefs each sail. Many icebergs in sight. At 10, light winds and cloudy weather. Vessel getting entangled amongst the small ice. Out all reefs. Midnight, tacked.

Wednesday, March 20.—A.M., increasing breeze and hazy. At 5, made sail. At 7, hard squalls, with snow and fog. Close reefed and hove to. At 11, kept away; set the jib. Latitude by account, 56° 10′ S.; longitude by account, 94° 19′ E. P.M., dark, squally weather, with snow and hail. At 8, ditto weather, with thick fog. Many icebergs. Heard some penguins. Hove to under close-reefed foresail and fore-staysail; sheet in midships.

Thursday, March 21.—A.M., strong gales, with snow and sleet, and a heavy sea on. At daylight saw several icebergs. At 8 set close-reefed mainsail and jib. Longitude by chronometer, 93° 10′ 30″ E.; latitude by chronometer, 55° 10′. At noon, clear weather, with snow squalls at intervals. *Sabrina* in company. Latitude by observation, 55° 2′ S.;

longitude by account, 93° 6′ E. P.M., ditto weather. At 4, longitude by chronometer, 93° 57′ E.; latitude, 54° 49′ S. Passed several small pieces of ice, and saw several penguins. At midnight, moderate, with less sea. Out two reefs. Several icebergs in sight. Aurora Borealis in sight the fore part of the night, with clear weather.

EXTRACT FROM THE "NARRATIVE OF THE U.S. EXPLORING EXPEDITION, 1838–42." BY CHARLES WILKES, U.S.N., COMMANDER OF THE EXPEDITION. VOL. II.

CHAPTER IX. (pp. 297–387).

THE subjects of which I am about to treat in the following chapters are exclusively nautical. I shall, therefore, adopt in treating them more the form of a log-book, and follow the daily order of their occurrence with more strictness than I have hitherto considered necessary. This will be done in order to illustrate more fully the nature of the remote regions we traversed, and for the purpose of giving a more exact relation of the incidents of this part of our cruise—incidents that I cannot but hope have made this part of our labours particularly interesting to all of our countrymen who possess a feeling of national pride.

The credit of these discoveries has been claimed on the part of one foreign nation, and their extent, nay, actual existence, called into question by another; both having rival expeditions abroad, one at the same time, the other the year succeeding.

Each of these nations, with what intent I shall not stop to inquire, has seemed disposed to rob us of the honour, by underrating the importance of their own researches, and would restrict the Antarctic land to the small parts they respectively saw. However willing I might be in a private capacity to avoid contesting their statements, and let truth make its own way, I feel it due to the honour of our flag to make a proper assertion of the priority of the claim of the American Expedition, and of the greater extent of its discoveries and researches.

That land does exist within the Antarctic Circle is now confirmed by the united testimony of both French and English navigators. D'Urville, the celebrated French navigator, within a few days after land was seen by the three vessels of our squadron, reports that his boats landed on a small point of rocks, at the place (as I suppose) which appeared accessible to us in Piner's Bay, whence the *Vincennes* was driven by a violent gale; this he called Clarie Land, and testifies to his belief of the existence of a vast tract of land, where our view of it has left no doubt of its existence. Ross, on the other hand, penetrated to the latitude of 79° S. in the succeeding year, coasted for some distance along a lofty country connected with our Antarctic continent, and establishes beyond all cavil the correctness of our assertion, that we have discovered,

not a range of detached islands, but a vast Antarctic continent. How far Captain Ross was guided in his search by our previous discoveries will best appear by reference to the chart, with a full account of the proceedings of the squadron, which I sent to him, and which I have inserted in Appendix XXIV. and Atlas; although I have never received any acknowledgment of their receipt from him personally, yet I have heard of their having reached his hands a few months prior to his Antarctic cruise. Of this, however, I do not complain, and feel only the justifiable desire to maintain the truth in relation to a claim that is indisputable. The following narrative must, I feel satisfied, leave no doubt in any unprejudiced mind of the correctness of the assertion that we have discovered a vast continent; but I would ask in advance, who was there prior to 1840, either in this country or in Europe, that had the least idea that any large body of land existed to the south of New Holland? And who is there that now doubts the fact, whether he admits it to be a vast continent, or contends that it is only a collection of islands?

Examine all the maps and charts published up to that time, and upon them will any traces of such land be found? They will not, and for the very best of reasons—none was known or even suspected to exist. We ourselves anticipated no such discovery; the indications of it were received with doubt and hesitation; I myself did not venture to record in my private journal the certainty of land until three days after those best acquainted with its appearance in these high latitudes were assured of the fact; and finally, to remove all possibility of doubt, and to prove conclusively that there was no deception in the case, views of the same land were taken from the vessels in three different positions, with the bearings of its peaks and promontories, by whose intersection their position is nearly as well established as the peaks of any of the islands we surveyed from the sea.

All doubt in relation to the reality of our discovery gradually wore away, and towards the close of the cruise of the *Vincennes* along the icy barrier, the mountains of the Antarctic continent became familiar and of daily appearance, insomuch that the log-book, which is guardedly silent as to the time and date of its being first observed, now speaks throughout of "the land."

After leaving Sydney we had, until the 31st December, fine weather and favourable winds. We took advantage of these, and all sail was crowded on the vessels of the squadron; at the above date we had reached the latitude of 43° S.

Under such circumstances the usual order of sailing, in a line abreast, was easily maintained, and the communications between the vessels were frequent. On the 31st of December I issued the sailing instructions for the cruise, which will be found in Appendix XXV.

During this favourable weather all hands were employed in tightening

the ports, in order to secure the interior of the vessels as much as possible from the cold and wet, which were to be apprehended in the region to which we were bound. For this purpose, after calking all the openings, the seams were covered with tarred canvas, over which strips of sheet-lead were nailed. The sailors exhibited great interest in these preparations, and studiously sought to make everything snug; all useless articles were stowed away in the hold, for we were in truth full to overflowing, and places at other times sacred were now crowded.

It was fortunate that the weather for the first few days was so favourable; for so full was every place that we had been compelled to stow bread in the launch and cutter, and this in bulk; or the quantity was so much beyond that which had been carried on any former occasion that a sufficient number of bags were not to be had, and in the hurry of its reception on board, time had not been found to provide them. Every ounce of bread thus exposed was looked to with solicitude, for there was a chance that all of it might be needed.

Among other preparations, rough casings of boards were built around all the hatches, having doors furnished with weights and pulleys, in order to insure that they should not be left open. Having thus provided for the exclusion of cold air, I contented myself with preparations for keeping the interior of the vessel at a temperature no higher than 50°. I deemed this preferable to a higher temperature, in order to prevent the injurious effects which might be produced by passing suddenly from below to the deck. I conceived it far more important to keep the air dry than warm, particularly as a lower temperature would have the effect of inducing the men to take exercise for the purpose of exciting their animal heat.

Aware that warm and dry clothing was an object of the first importance, inspections of the men's feet and dress were held morning and evening, in which the wearing of a suitable number of garments was insisted upon, as well as the greatest personal cleanliness. With the same views the drying stoves were particularly attended to; and that every part under deck might be effectually and quickly freed of moisture, additional stoves had been procured at Sydney. Thermometers were hung up in proper places and frequently consulted, in order by following their indications to secure an equable temperature, and at the time to ascertain when the use of stoves might be dispensed with, in whole or in part. The latter was an important consideration, for we were under the necessity of husbanding our stock of fuel by expending it only when absolutely necessary.

We also took advantage of the fine weather to bend all our best sails and to shift our topgallant masts.

The 1st January was one of those days which are termed, both at sea and on shore, a weather-breeder. The sea was smooth and placid, but the sky was in places lowering and had a wintry cast, to which

we had long been strangers; the temperature shortly began to fall, the breeze to increase, and the weather to become misty. In a few hours we were sailing rapidly through the water, with a rising sea, and by midnight it was reported that the tender, *Flying-Fish*, was barely visible. I shortened sail, but it was difficult to stop our way; and on the morning of the 2nd of January the fog was dense, and the *Peacock* and *Porpoise* only were in sight; we hove to, and the *Peacock* and *Porpoise* were ordered to stand east and west, in order to intercept the tender, but they returned without success; we also fired guns in hopes of being heard. In the afternoon I deemed it useless to wait any longer for her, and that I must take the chance of falling in with her at Macquarie Island, our first appointed place of rendezvous—a visit to which I had flattered myself might have been avoided, but which it became necessary now to make. We accordingly proceeded on our course for that island, with all sail set. This separation of the tender took place in the latitude of 48° S., and she was not again seen until our return. The officers and crew were not slow in assigning to the *Flying-Fish* a similar fate with her unfortunate mate the *Seagull*. Men-o'-war's men are prone to prognosticate evil, and on this occasion they were not wanting in various surmises. Woeful accounts were soon afloat of the distress the schooner was in when last seen—and this in quite a moderate sea.

The barometer now began to assume a lower range, and the temperature to fall below 50°. On the 3rd, the fog continuing very thick, the *Peacock* got beyond hearing of our horns, bells, drums, and guns, and was parted with. This, however, I did not now regret so much, as it was of little consequence whether we sought one or two vessels at our rendezvous, although it might cause a longer detention there.

The wind was now (5th January) veering rapidly to the north-west, with some thunder and lightning, and we in consequence expected the wind to haul to the south-west, but, to my surprise, it went back to the north-east, with thick rainy weather. This return of the wind to its old quarter followed a fall of the barometer to 29·60 in., and in a few hours afterwards to 29·30 in., while the weather continued moderate; a large number of albatrosses, Port Egmont hens, and petrels were seen.

For the last few days we were unable to get any observations, but on the 6th we were favoured with a sight of the sun, and found ourselves in the latitude of 53° 30′ S., and longitude 157° 35′ E. Our variation had increased to fifteen and-a-half degrees easterly. This being a fine day, we completed our calking and the more effectual securing of the ship. At midnight we were about 50 miles from Macquarie Island.

The morning of the 7th was misty, with squally weather. A heavy sea rising, and a strong gale setting in, we lost sight of the *Porpoise* for a few hours. Being unable to see beyond an eighth of a mile, it was thought imprudent to run, for fear of passing the island, and we hove to

to await its moderating. It cleared at noon, and we obtained an observation, by which we found ourselves in latitude 54° 20′ S., and longitude 160° 47′ E. I found that we had been carried to the eastward upwards of 20 miles in less than 18 hours; this, with the wind hauling to the south-west, brought us to leeward of the island, and the sea and wind increasing, I saw it was useless to attempt to reach it without great loss of time. I therefore bore off to the southward for our second rendezvous, Emerald Island, or its supposed locality.

On the morning of the 8th the wind, which continued from the same quarter, with heavy cumulous clouds, began to moderate, and we were enabled to make more sail. By our observations we found a current setting to the south-east, of one mile an hour. Our longitude was 162° 13′ E., latitude 55° 38′ S.; the barometer stood at 30·00 in., the temperature had fallen to 38°; and this change, on account of the rawness of the air, was much felt by the crew.

During the 9th we passed the site of Emerald Isle, situate, as has been stated, in latitude 57° 15′ S., and longitude 162° 30′ E., but saw nothing of it, nor any indications of land, which I therefore infer does not exist in the locality where it is laid down. We again experienced the south-east current of 20 miles a day. Our variation had increased to 22 degrees easterly. Making our course with all sail set, the *Porpoise* in company, we passed to-day some pieces of kelp. The temperature continued at 38°; numerous flocks of grey petrels around us.

The 10th we encountered the first iceberg, and the temperature of the water fell to 32°. We passed close to it, and found it a mile long and 180 feet in height. We had now reached the latitude of 61° 08′ S., and longitude 162° 32′ E. The current to-day set in the same direction as before, about half-a-mile per hour. The second iceberg was 30 miles, and the third about 55 miles south of the first. These ice-islands were apparently much worn by the sea into cavities, exhibiting fissures as though they were ready to be rent asunder, and showed an apparent stratification, much inclined to the horizon. The weather now became misty, and we had occasionally a little snow; I congratulated myself that we had but few on the sick list and all were in high spirits at the novelty of the cruise. We continued to meet icebergs of different heights, some of which, though inclined to the horizon, had a plane upper surface.

11th. The fair wind from the north-west (accompanied with a light mist, rendering objects on the horizon indistinct) still enabled us to pursue our courses southerly. Icebergs became so numerous as to compel us occasionally to change our course. They continued of the same character, with caverns worn in their perpendicular sides, and with flat tops, but the latter were now on a line with the horizon. Towards 6 p.m. we began to perceive smaller pieces of ice, some of which were not more than an eighth of a mile in length, floating as it

were in small patches. As the icebergs increased in number the sea became smoother, and there was no apparent motion. Between 8 and 9 p.m. a low point of ice was perceived ahead, and in a short time we passed within it. There was now a large bay before us. As the vessel moved rapidly, at 10.30 p.m. we had reached its extreme limits, and found our further progress entirely stopped by a compact barrier of ice, enclosing large square icebergs. The barrier consisted of masses closely packed, and of every variety of shape and size. We hove to until full daylight; the night was beautiful, and everything seemed sunk in sleep, except the sound of the distant and low rustling of the ice that now and then met the ear. We had now reached the latitude of 64° 11′ S., longitude 164° 30′ E., and found our variation 22 degrees easterly. One and all felt disappointed, for we had flattered ourselves that the way was open for further progress to the southward, and had imbibed the impression (from the extraordinary weather we had at Sydney, and the reports of icebergs having been seen farther to the northward than usual, by all the vessels arriving) that the season would be an open one. What surprised me most was a change in the colour of the water to an olive-green, and some faint appearances resembling distant land; but as it was twilight, and I did not believe the thing credible, I put no faith in these indications, although some of the officers were confident they were not occasioned by icebergs. The barometer stood at 29·200 in.; the temperature of the air 33°, water 32°. We lay to until 4 o'clock. As it grew light, on the 12th, a fog set in so thick that we lost sight of the *Porpoise*, and could not hear any answer to our signals. I therefore determined to work along the barrier to the westward.

We were all day beating in a thick fog, with the barrier of ice close to us, and occasionally in tacking brought it under our bow; at other times we were almost in contact with icebergs. During the whole day we could not see at any time further than a quarter of a mile, and seldom more than the ship's length. The fog, or rather thick mist, was forming in ice on our rigging. From the novelty of our situation, and the excitement produced by it, we did not think of the danger. I shall now leave the *Vincennes* and *Porpoise* pursuing their course to the westward with a head wind, and bring the *Peacock* up to the barrier.

Previously to parting company on the 3rd of January, the crew of that ship had also been engaged in building hurricane-houses, calking and chintzing, to secure them from the wet and cold. After parting company, Captain Hudson immediately steered for the first rendezvous, Macquarie Island, and was more fortunate than we were in reaching it, although the *Peacock* had experienced the same kind of weather that we had, and currents setting to the eastward.

On approaching the island they discovered large patches of kelp, and saw numerous procellaria and albatrosses about the ship. On the 10th of January they made the island, and observed a reef of rocks extending

three-quarters of a mile off its south end. Passing within a short distance of it, they did not observe any of the signals of the squadron flying as they had anticipated. They, notwithstanding, stood in, lowered a boat, and despatched several officers to put up the signal, make experiments, and collect specimens. The boat approached an indentation on the west side, too open to be called a bay, and found that

MACQUARIE ISLAND.

the surf was running high, and beating with great violence against the rocks, which, together with the kelp, rendered it dangerous to attempt landing. They made for several other places which looked favourable at a distance, but on approaching them, they were found even less accessible. The boat then returned to the first place to make another attempt, which was attended with great difficulty. The boat's anchor was dropped, and she was backed in with great caution to the edge of the rollers; the surf was very high, and rolled in with a noise like thunder, breaking furiously upon the rocks, so as to make the boat fairly tremble, and threatening every moment to overwhelm her; once or twice she was prevented from getting broadside-to by hauling out towards her anchor. At length, after a dozen fruitless attempts, and awaiting a favourable opportunity, Mr. Eld, and a quarter-master, succeeded in getting ashore, but not without being immersed up to their breasts. It was found impossible to land any instruments, and the quarter-master was despatched to erect the necessary signals, while Mr. Eld proceeded to visit the penguin-rookery not far distant. On approaching the island it had appeared to be covered with white spots; these excited conjecture, but after landing, the exhalations rendered it not long doubtful that it was birdlime.

Mr. Eld, in his journal, gives the following account of his visit:— "Although I had heard so often of the great quantity of birds on the uninhabited islands, I was not prepared to see them in such myriads as here. The whole sides of the rugged hills were literally covered with them. Having passed a deep fissure in the rocks, I ascended a crag that led to what I thought was their principal roost, and at every step my astonishment increased. Such a din of squeaking, squalling, and gabbling I never before heard, or dreamed could be made by any of the feathered tribe. It was impossible to hear one's self speak. It appeared as if everyone was vying with his neighbour to make the greatest possible noise. I soon found my presence particularly displeased them,

for they snapped at me in all directions, catching hold of my trousers, shaking and pinching my flesh so violently as to make me flinch and stand upon the defensive. As we wanted a number of specimens, I commenced kicking them down the precipice, and knocked on the head those which had the temerity to attack me. After having collected a number, and a few eggs, I laid them aside, whilst I ascended higher on the hill. I had not left them more than eighteen feet, before two albatrosses came down and commenced picking at the dead birds I had just killed, but not being able to make any impression upon them, deliberately picked up two of the eggs with their beaks, and, in spite of my efforts to prevent it, flew away with them. The eggs were about the size of a goose's; the original colour seemed to have been white, but they were so dirty that it was difficult to say with certainty. They were no doubt the eggs of a penguin, as I took them out of their nest, which was only a small place scratched in the earth, just big enough to hold one or two eggs, with little or no grass, sticks, or anything else to form a nest of. I afterwards picked up a number of these eggs, and another was found of the size of a hen's egg, white, with a slight tinge of green. On mounting still higher, which was very steep, and composed of volcanic rock, loose stones, and a little soil mixed with birdlime, I found that there were more of these birds than I anticipated. The nests were within two feet of each other, with one or two young ones in each; one of the old ones watching and sitting on the nest, whilst the young were trying ineffectually to nestle themselves under the small wings of the old ones. The appearance of the young was not unlike that of goslings, being covered with a dark thick down.

"These penguins are the *Eudyptes chrysocome*; they are from sixteen to twenty inches in height, with white breast and nearly black back, the rest being of a dark dove-colour, with the exception of the head, which is adorned on each side with four or five yellow feathers, three or four inches long, looking like graceful plumes. The birds stand erect in rows, which gives them the appearance of Liliputian soldiers. The sight was novel and beautiful, and had it not been for the gabble—enough to deafen me—I could have stayed much longer. It was now time to return to the boat, when it occurred to me that live birds would be preferable to the dead; so, throwing the latter down, I seized one old and a couple of young ones, and with three or four eggs in my cap, made the best of my way to the boat. It was now found impossible to hand them on board, and not willing to surrender my prize, a lead-line was thrown me from the boat, but did not come near enough, and in my attempts to get it, I was overtaken by a sea, and was thrown violently against the rocks among the kelp, and just made out to crawl on hands and knees beyond the reach of the returning sea, somewhat bruised, wet, and benumbed with the cold."

At this juncture, the quarter-master returned with a large species of

penguin over his shoulders, but without the crown of feathers on his head. He described a similar rookery, and also saw some green paroquets with a small red spot on the head, and an oblong slaty or purple spot at the root of the bill, and with straight beaks. Mr. Eld was too much exhausted to return with him to get specimens, and the hour being late, it was necessary to return to the boat, which had been waiting for some time for them. The quarter-master succeeded in getting his penguins to the boat, but Mr. Eld's began floundering about, and although their legs were tied, managed to get into the water, where they were at home, and were soon out of reach. The tying of the legs, did not seem any impediment to their exertions in the water, and thus several interesting specimens of natural history were lost, the trouble that it cost making them doubly valuable. With great difficulty Mr. Eld reached the boat, for having again missed his foothold, he fell among the kelp, but by the timely aid of those on board he was rescued. After an hour's tug at their oars they reached the ship in safety. During their absence the ship sounded with a line of three hundred fathoms, two and a-half miles from the shore, but no bottom was found. The temperature of the water at the surface was 43°, and at 300 fathoms deep 39°. The current was tried, but none found. The south end of Macquarie Island lies in latitude 54° 44′ S., and longitude 159° 49′ E. The island is high and much broken; it is apparently covered with verdure, although a long, tufted rank grass was the only plant seen by those who landed.

The highest peak on the island is from 1200 to 1500 feet high, and as far as our observations extended, it had neither tree nor shrub on it. At 6 p.m. the ship filled away, and at eight was abreast of the Bishop and Clerk. Macquarie Island affords no inducement for a visit, and as far as our examination went, has no suitable place for landing with a boat. The only thing I had to regret was not being able to make it a magnetic station.

On the 11th and 12th nothing particular occurred on board the *Peacock*. All sail was set, and running to the southward on the 13th, in latitude 61° 30′ S., longitude 161° 05′ E., the first ice-islands were seen; the dip was observed with Lloyd's and Dolland's needles, which made it 86° 58′. There was no occasion on the night of the 13th to light the binnacle-lamps, as newspaper print could be read with ease at midnight. On the 14th, while still making much progress to the south, and passing occasionally icebergs and brash ice, the water appeared somewhat discoloured. Robinson's, Lloyd's, and Dolland's needles gave, the same day, in the cabin, 86° 37′ for the dip, and in the ward-room 86° 46′. Albatrosses, Cape pigeons, and other birds about.

On the 15th they passed many ice-islands. The weather was thick, and snow fell at intervals; the wind continued from the westward. Many whales were seen; albatrosses, petrels, and Cape pigeons were

frequent about the ship. At 4 p.m. the mist raised a little, and to their surprise they saw a perfect barrier of ice extending to the south-west, with several large icebergs enclosed within it; shortly after they discovered a sail, which proved to be the *Porpoise*.

The *Vincennes* and *Porpoise* were left in our narrative near the icy barrier, separated by the fogs and mists that prevailed at times. The *Porpoise*, on the 13th, in latitude 65° 08′ S., longitude 163° E., discovered several sea-elephants on the ice, and sent a boat to capture them, but without success. The current was tried, and found to set west one-fifth of a mile per hour. Some time afterwards, seeing some sea-elephants near the edge of the ice, a boat was sent, and succeeded in capturing a female. From the numerous sea-elephants, and the discoloration of the water and ice, they were strongly impressed with the idea of land being in the vicinity, but on sounding with 100 fathoms no bottom was found. Lieutenant-Commandant Ringgold felt convinced, from the above circumstances, and the report that penguins were heard, that land was near, and thought he could discern to the south-east something like distant mountains. A nearer approach was impossible, as they were then in actual contact with the icy barrier.

On the 14th, at 3 p.m., the water being still discoloured, tried soundings, but found no bottom.

Two sea-elephants were seen lying motionless on the ice. On being shot at, the animal would raise its head and look around for an instant, and then resume its former posture. Boats were lowered, when they were captured and brought on board: they proved to be the *Phoca proboscidea*. Dr. Holmes examined their stomachs, and found nothing but well-digested food. Their dimensions were as follows:—

	ft.	in.
Total length	10	9
Length of posterior flipper	1	9
Length of flippers	2	4
Circumference of largest part of body	6	3

This was a young female. The other was taken afterwards; he measured—

	ft.	in.
In length	8	6
Greatest circumference behind anterior flipper	5	0
Length of flippers	1	5
Breadth	1	5

On the 15th the *Peacock* and *Porpoise* were in company; the specimens of sea-elephants were put on board the *Peacock*, and after having had communication with each other the vessels again separated, standing on opposite tacks.

On the 16th the three vessels were in longitude 157° 46′ E., and all within a short distance of each other. The water was much discoloured, and many albatrosses, Cape pigeons, and petrels were seen about the

ships. On board the *Vincennes* we sounded with 230 fathoms and found no bottom; the water had the appearance of an olive-green colour, as if but 40 and 50 fathoms deep. At the surface its temperature was 32°, at the depth sounded, 31°. I should have tried for a deeper cast, but the line was seen to be stranded, when we were obliged to stop; we fortunately saved our apparatus, with Six's thermometers.

On this day (16th January) appearances believed at the time to be land were visible from all the three vessels, and the comparison of the three observations, when taken in connection with the more positive proofs of its existence afterwards obtained, has left no doubt that the appearance was not deceptive. From this day, therefore, we date the discovery which is claimed for the squadron.

On board the *Peacock*, it appears that Passed Midshipmen Eld and Reynolds both saw the land from the masthead and reported it to Captain Hudson: he was well satisfied, on examination, that the appearance was totally distinct from that of ice-islands, and a majority of the officers and men were also satisfied that if land could exist, that was it. I mention particularly the names of these two gentlemen, because they have stated the same fact under oath, before the court-martial, after our return.

On board the *Porpoise*, Lieutenant-Commandant Ringgold states that "he went aloft in the afternoon, the weather being clear and fine, the horizon good, and clouds lofty; that he saw over the field-ice an object, large, dark, and rounding, resembling a mountain in the distance; the icebergs were all light and brilliant, and in great contrast." He goes on to say, in his report, "I watched for an hour to see if the sun in his decline would change the colour of the object: it remained the same, with a white cloud above, similar to that hovering over high land. At sunset the appearance remained the same. I took the bearings accurately, intending to examine it closely as soon as we got a breeze. I am thoroughly of opinion it is an island surrounded by immense fields of ice. The *Peacock* in sight to the southward and eastward over the ice; the sun set at a few minutes before ten; soon after, a light air from the southward, with a fog-bank arising, which quickly shut out the field-ice."

In Passed Midshipman Eld's journal, he asserts that he had been several times to the masthead during the day, to view the barrier; that it was not only a barrier of ice but one of *terra firma*. Passed Midshipman Reynolds and himself exclaimed, with one accord, that it was land. Not trusting to the naked eye, they descended for spy-glasses, which confirmed, beyond a doubt, their first impressions. The mountains could be distinctly seen, over the field-ice and bergs, stretching to the south-west as far as anything could be discerned. Two peaks, in particular, were very distinct (which I have named after those two officers), rising in a conical form; and others, the lower parts of which were quite as

distinct, but whose summits were lost in light fleecy clouds. Few clouds were to be seen in any other direction, for the weather was remarkably clear. The sun shone brightly, on ridge after ridge, whose sides were partially bare; these connected the eminences I have just spoken of, which must be from 1000 to 2000 feet high. Mr. Eld further states, that on reporting the discovery to Captain Hudson, the latter replied that there was no doubt of it, and that he believed that most of the icebergs then in sight were aground. At this time they were close in with the barrier, and could approach no nearer. On this day the *Peacock* got a cast of the deep-sea lead, with Six's thermometer attached, to the depth of 850 fathoms, only a short distance from the barrier; the temperature of the surface was 31°, and at the depth sounded 31½°; current one-fourth of a mile, north-by-east.

The log-book of the *Porpoise* has also this notice in it: "From six to eight, calm and pleasant, took in studding-sails; at seven set maintop-gallant studding-sail; discovered what we took to be an island, bearing south-by-east; a great deal of field-ice in sight; noticed penguins around the brig.—(Signed) T. H. NORTH." Dr. Holmes, on the same evening, noted in his journal a marked appearance of land.

On board the *Vincennes* there was on the same day much excitement among the crew. All eagerly watched the flight of birds, together with the whales and penguins, and spoke of the proximity of land, which, from the appearance of never-failing signs, could scarcely be doubted. The following is a sketch which I made of what I myself saw, and have

SKETCH OF LAND AND FIELD-ICE.

called Ringgold's Knoll, on the chart, and which at the same time will show the field-ice* as it appeared.

This night we were beating with frequent tacks, in order to gain as much southing as possible. Previous to its becoming broad daylight

* The field-ice is composed of a vast number of pieces, varying in size, and separated from one another, the long swell keeping the outer ones always in motion. The smallest pieces were about 6 feet in diameter, while the largest sometimes exceeded 500 or 600 feet. Their depth below the surface varies still more, and some appear to be soft, while others were hard and compact. The depth of these does not probably in any case exceed 20 feet. Most of them, and particularly the larger ones, had a covering of about 18 inches of snow. The whole at a distance appeared like a vast level field, broken up as it were by the plough, and presenting shapeless angular masses of every possible figure, while here and there a table-topped iceberg was enclosed.

the fog rendered everything obscure, even at a short distance from the ship. I knew that we were in close proximity to icebergs and field-ice, but from the report of the look-out, at sunset, believed that there was an opening or large bay leading to the southward. The ship had rapid way on her, and was much tossed about, when in an instant all was perfectly still and quiet; the transition was so sudden that many were awakened by it from sound sleep, and all well knew, from the short experience we had had, that the cessation of the sound and motion usual at sea was a proof that we had run within a line of ice—an occurrence from which the feeling of great danger is inseparable. The watch was called by the officer of the deck, to be in readiness to execute such orders as might be necessary for the safety of the ship. Many of those from below were seen hurrying up the hatches, and those on deck straining their eyes to discover the barrier in time to avoid accident. The ship still moving rapidly along, some faint hope remained that the bay might prove a deep one, and enable me to satisfy my sanguine hopes and belief relative to the land.

The feeling is awful, and the uncertainty most trying thus to enter within the icy barrier blindfolded as it were by an impenetrable fog, and the thought constantly recurring that both ship and crew were in imminent danger; yet I was satisfied that nothing could be gained but by pursuing this course. On we kept, until it was reported to me, by attentive listeners, that they heard the low and distant rustling of the ice. Suddenly a dozen voices proclaimed the barrier to be in sight, just ahead. The ship, which a moment before seemed as if unpeopled, from the stillness of all on board, was instantly alive with the bustle of performing the evolutions necessary to bring her to the wind, which was unfavourable to a return on the same track by which we had entered. After a quarter of an hour, the ice was again made ahead, and the full danger of our situation was realised. The ship was certainly embayed, and although the extent of sea-room to which we were limited was rendered invisible by the dark and murky weather, yet, that we were closely circumscribed was evident from having made the ice so soon on either tack, and from the audible rustling around us. It required several hours to extricate the ship from this bay.

Few are able to estimate the feelings that such an occasion causes to a commander, who has the responsibility of the safety of ship and crew operating as a heavy weight upon his heart, and producing a feeling as if on the verge of some overwhelming calamity. All tends to satisfy him that nothing could guide him in safety through or shield from destruction those who have been entrusted to his charge but the hand of an all-wise Providence.

17th.—In the morning we discovered a ship, apparently within a mile of us, to which we made signal and fired a gun, but she was shortly after lost sight of. We also saw the brig to the eastward, close to the

barrier of ice. In the afternoon we spoke the *Peacock*. She had not seen us in the morning, and I should be disposed to believe that the cause of her image appearing so close to us in the morning was produced by refraction above a low fog-bank; but the usual accompaniment of such phenomena (a difference of temperature below and aloft) did not exist.

I now desired Captain Hudson to make the best use of his time in exploring, as to attempt to keep company would only impede our progress, and, without adding to our safety, might prevent the opportunity of examining the barrier for an opening. I was also satisfied that the separation would be a strong incentive to exertion, by exciting rivalry among the officers and crews of the different vessels. This day at noon we were in latitude 66° 20′ S., longitude 156° 02′ E. Many petrels, albatrosses, a few whales, and a seal were seen from the ship, and the water was quite green.

18*th*.—The weather this day was variable, with light westerly winds; the temperature of air and water 32°. Occasional squalls of snow and mist occurred, but it was at times clear. The water was still olive-green, and the other vessels occasionally in sight, beating to windward.

On the morning of the 19th we found ourselves in a deep bay, and discovered the *Peacock* standing to the south-west. Until 8 a.m. we had a moderate breeze. The water was of a darker olive-green, and had a muddy appearance. Land was now certainly visible from the *Vincennes*, both to the south-south-east and south-west, in the former direction most distinctly. Both appeared high. It was between eight and nine in the morning when I was fully satisfied that it was certainly land, and my own opinion was confirmed by that of some of the oldest and most experienced seamen on board. The officer of the morning watch, Lieutenant Alden, sent twice and called my attention to it. We were at this time in longitude 154° 30′ E., latitude 66° 20′ S.; the day was fine and at times quite clear, with light winds. After divine service, I still saw the outline of the land, unchanged in form, but not so distinct as in the morning. By noon I found we were sagging on to the barrier; the boats were lowered in consequence, and the ship towed off. The report from aloft was, "A continued barrier of ice around the bay, and no opening to be seen, having the western point of it bearing to the northward of west of us." I stood to the westward to pass around it, fully assured that the *Peacock* would explore all the outline of the bay.

The *Peacock*, at 3 h. 30 m., according to Captain Hudson's journal, having got into the drift-ice, with a barrier still ahead to the west, tacked to the south-east to work up for an immense mass, which had every appearance of land, and which was believed to be such by all on board. It was seen far beyond and towering above an ice-island that was from 150 to 200 feet in height. It bore from them about south-

west,* and had the appearance of being 3000 feet in height, forming a sort of amphitheatre, looking grey and dark, and divided into two distinct ridges or elevations throughout its entire extent, the whole being covered with snow. As there was no probability of getting nearer to it in this quarter, they stood out of the bay, which was about twenty miles deep, to proceed to the westward, hoping to get an opportunity to approach the object more closely on the other side.

We had a beautiful and unusual sight presented to us this night: the sun and moon both appeared above the horizon at the same time, and each throwing its light abroad. The latter was nearly full. The former illuminated the icebergs and distant continent with his deep golden rays; while the latter, in the opposite horizon, tinged with silvery light the clouds in its immediate neighbourhood. There now being no doubt in any mind of the discovery of land, it gave an exciting interest to the cruise, that appeared to set aside all thought of fatigue, and to make every one willing to encounter any difficulty to effect a landing.

20th.—This day, on board the *Peacock*, they witnessed a sea-fight between a whale and one of its many enemies. The sea was quite smooth, and offered the best possible view of the whole combat. First, at a distance from the ship, a whale was seen floundering in a most extraordinary way, lashing the smooth sea into a perfect foam, and endeavouring apparently to extricate himself from some annoyance. As he approached the ship, the struggle continuing and becoming more violent, it was perceived that a fish, apparently about 20 feet long, held him by the jaw, his contortions, spouting, and throes, all betokening the agony of the huge monster. The whale now threw himself at full length from the water with open mouth, his pursuer still hanging to the jaw, the blood issuing from the wound and dyeing the sea to a distance around; but all his flounderings were of no avail; his pertinacious enemy still maintained his hold, and was evidently getting the advantage of him. Much alarm seemed to be felt by the many other whales around. These "killers," as they are called, are of a brownish colour on the back and white on the belly, with a long dorsal fin. Such was the turbulence with which they passed, that a good view could not be had of them to make out more nearly the description. These fish attack a whale in the same way as dogs bait a bull, and worry him to death They are armed with strong sharp teeth, and generally seize the whale by the lower jaw. It is said that the only part of them they eat is the tongue. The whalers give some marvellous accounts of these killers, and of their immense strength, among them, that they have been known to drag a whale away from several boats which were towing it to the ship.

There was a great quantity of animalculæ in the water, and some

* Sketches of this land will be seen in the atlas on the chart of Antarctic Continent.

large squids (Medusæ), and quantities of shrimp were frequently seen about the icebergs; these are no doubt the attractions which bring whales to frequent these seas.

The last two days we had very many beautiful snow-white petrels about. The character of the ice had now become entirely changed, The tabular-formed icebergs prevailed, and there was comparatively little field-ice. Some of the bergs were of magnificent dimensions, one-third of a mile in length, and from 150 to 200 feet in height, with sides perfectly smooth, as though they had been chiselled. Others, again, exhibited lofty arches of many-coloured tints, leading into deep caverns, open to the swell of the sea, which, rushing in, produced loud and distant thunderings. The flight of birds passing in and out of these caverns recalled the recollection of ruined abbeys, castles, and caves, while here and there a bold projecting bluff, crowned with pinnacles and turrets, resembled some Gothic keep. A little farther onwards would be seen a vast fissure, as if some powerful force had rent in twain these mighty masses. Every noise on board, even our own voices, reverberated from the massive and pure white walls. These tabular bergs are like masses of beautiful alabaster; a verbal description of them can do little to convey the reality to the imagination of one who has not been among them. If an immense city of ruined alabaster palaces can be imagined, of every variety of shape and tint, and composed of huge piles of buildings grouped together, with long lanes or streets winding irregularly through them, some faint idea may be formed of the grandeur and beauty of the spectacle. The time and circumstances under which we were viewing them, threading our way through these vast bergs, we knew not to what end, left an impression upon me of these icy and desolate regions that can never be forgotten.

22*nd*.—It was now, during fine weather, one continued day; but we had occasional snow-squalls that produced an obscurity that was tantalising. The bergs were so vast and inaccessible that there was no possibility of landing upon them.

The *Peacock* and *Porpoise* were in sight of each other this day. A large number of whales, albatrosses, petrels, penguins, &c., were seen around, and a flock of ducks was also reported as having been seen from the *Vincennes*, as well as several seals. The effect of sunrise, at a little after 2 a.m. on the 23rd, was glorious.

As the events which occurred on board the *Peacock* during the next few days are particularly interesting, I shall proceed to narrate them in detail, leaving the *Vincennes* and *Porpoise* to pursue their route along their dangerous and novel pathway, and would particularly refer the reader to the actual condition of the *Peacock*, a statement of which has been heretofore given, that it may be borne in mind that our vessels had no planking, extra fastening, or other preparations for these icy regions, beyond those of the vessels of war in our service.

The *Peacock* stood into the bay which the *Vincennes* had found closed the day before, and saw the same appearance of high land in the distance. The water was much discoloured, and of a dark, dirty green. They hove-to, for the double purpose of getting a cast of the lead, and of lowering the boats to carry the instruments to a small iceberg, on which it was possible to land for the purpose of making magnetic observations. A line of 1400 fathoms was prepared to sound, and to the lead was attached the cylinder with Six's thermometer; the wind being fresh, several leads at different distances were attached to the line; they were not aware that the lead-line had touched bottom until they began to haul-in, when it was found that the lead bent on at 500 fathoms was filled with blue and slate-coloured mud. Attached to the lead also was a piece of stone, and a fresh bruise on it, as though the lead had struck heavily on rock. The remainder of the line had evidently lain on the bottom, as the copper cylinder was covered with mud, and the water inside of it was quite muddy. They then beat up a short distance to windward, and again sounded, when, with the line hanging vertically, bottom was reached at 320 fathoms; the matter brought up was slate-coloured mud. The temperature of the water at the surface was 32°, and at the above depth 27½°, being a decrease of 4½°.

The boats now returned, and on approaching the ship the persons in them were much startled by hearing the crew cheer ship in consequence of finding soundings. This was a natural burst of joy on obtaining this unquestionable proof that what they saw was indeed the land; a circumstance that, while it left no doubt, if any had existed, in the mind of any one on board the *Peacock*, that what they had previously seen was truly *terra firma*, furnished a proof that cannot be gainsaid, even by those disposed to dispute the evidence of sight unsupported by so decisive a fact. Mr. Eld and Mr. Stuart, in the boats, succeeded in getting observations, and the mean dip by the needles was 86° 16′.

Mr. Eld's boat succeeded in taking a king-penguin of enormous size, viz. from tip of tail to the bill, 45 inches, across the flippers, 37 inches, and the circumference of the body, 33 inches. He was taken after a truly sailor-like fashion by knocking him down. The bird remained quite unmoved on their approach, or rather showed a disposition to come forward to greet them. A blow with the boat-hook, however, stunned him, and before his recovery he was well secured. He showed, on coming to himself, much resentment at the treatment he had received, not only by fighting, but by an inordinate noise. He was in due time preserved as a specimen, and now graces the collection at Washington. In his craw were found thirty-two pebbles, from the size of a pea to that of a hazel-nut.

Bergs and field-ice were in various directions around; they had light baffling winds, clear and pleasant weather, with a smooth sea. The water was of a dark green colour. Standing into the bay for the purpose

of approaching the land, they at 5 a.m. passed through drift-ice into an open space, and when they had again approached the field, hove-to for the purpose of sounding. Here bottom was found at the depth of 800 fathoms, and the matter brought up was similar to that obtained the day before. The distance between the points where these two soundings were obtained was but short.

At 8.30 a.m., while attempting to box off the ship from some ice under the bow she made a stern-board, which brought the stern so forcibly in contact with another mass of ice that it seemed from the shock as if it were entirely stove in; the rudder was so much canted from its position as to carry away the starboard wheel-rope, and to wrench the neck of the rudder itself in such a manner as to render it unserviceable, or even worse than useless. In hopes of lessening the difficulty, relieving tackles were applied to the tiller, but without effect, for it was discovered that the rudder had been so far twisted as to make a considerable angle with the keel, and every exertion to move it proved ineffectual.

All hands were now called, and every officer and man was speedily at his station. The ship was found to be rapidly entering the ice, and every effort to direct her course by the management of the sails proved fruitless. In this helpless condition scarcely a moment passed without a new shock in some quarter or other from the ice, and every blow threatened instant destruction. The hope was not yet abandoned that some temporary expedient might be found to bring the rudder again into use, until they should be extricated from this perilous situation. A stage was, therefore, rigged over the stern, for the purpose of examining into its state, but it was found to be so much injured that it was impossible to remedy its defects while in its place, and preparations were forthwith made for unshipping it. In the meantime the position of the vessel was every instant growing worse, surrounded as she was by masses of floe-ice, and driving further and further into it, towards an immense wall-sided iceberg. All attempts to get the vessel on the other tack failed, in consequence of her being so closely encompassed, and it was therefore thought expedient to attempt to bring her head round, by hanging her to an iceberg by the ice-anchors, and thus complete what had been partially effected by the sails. The anchor was attached, but just at the moment the hawser was passed on board the ship took a start so suddenly astern that the rope was literally dragged out of the men's hands before they could get a turn around the bits.

The ship now drove stern foremost into the midst of the huge masses of ice, striking the rudder a second time. This blow gave the finishing stroke by nearly wringing off the head, breaking two of the pintles, and the upper and lower brace.

The wind now began to freshen and the floe-ice to set upon the ship; the sails were furled, and spars rigged up and down the ship's side as

fenders. Attempts were again made to plant the ice-anchors, for which purpose the boats were lowered; but the confined space, and the force with which the pieces of ice ground against each other was so great, that the boats proved nearly as unmanageable as the ship. After much exertion, however, the ice-anchors were planted and the hawser hauled taut. Here they for a time enjoyed comparative security, as the vessel hung by the anchors, which were planted in a large floe; the ice continued to close in rapidly upon them, grinding, crushing, and carrying away the fenders; and the wind, that had changed to seaward, rose with appearances that foreboded bad weather.

At 10.30 this security was at an end, for the anchors, in spite of the exertions of the officers and men who were near them, broke loose, and the ship was again at the mercy of huge floating masses. A rapid sternboard was the consequence; and a contact with the ice-island, vast, perpendicular, and as high as the mastheads, appeared inevitable.

Every possible preparation was made to meet the expected shock. There was no noise or confusion, and the self-possession and admirable conduct of the Commander inspired courage and confidence in all. Preparations were made to cock-bill the yards, and spars were got out.

While these preparations were going forward the imminence of the danger lessened for a while; the anchors again held, and there was a hope that they might bring the vessel up before she struck. This hope, however, endured but for a moment; for the anchors, with the whole body of ice to which they were attached, came in, and the ship going astern, struck quartering upon a piece of ice which lay between her and the great ice-island. This afforded the last hope of preventing her from coming into contact with it; and this hope failed also; for, grinding along the ice, she went nearly stern foremost, and struck with her larboard quarter upon the ice-island with a tremendous crash.

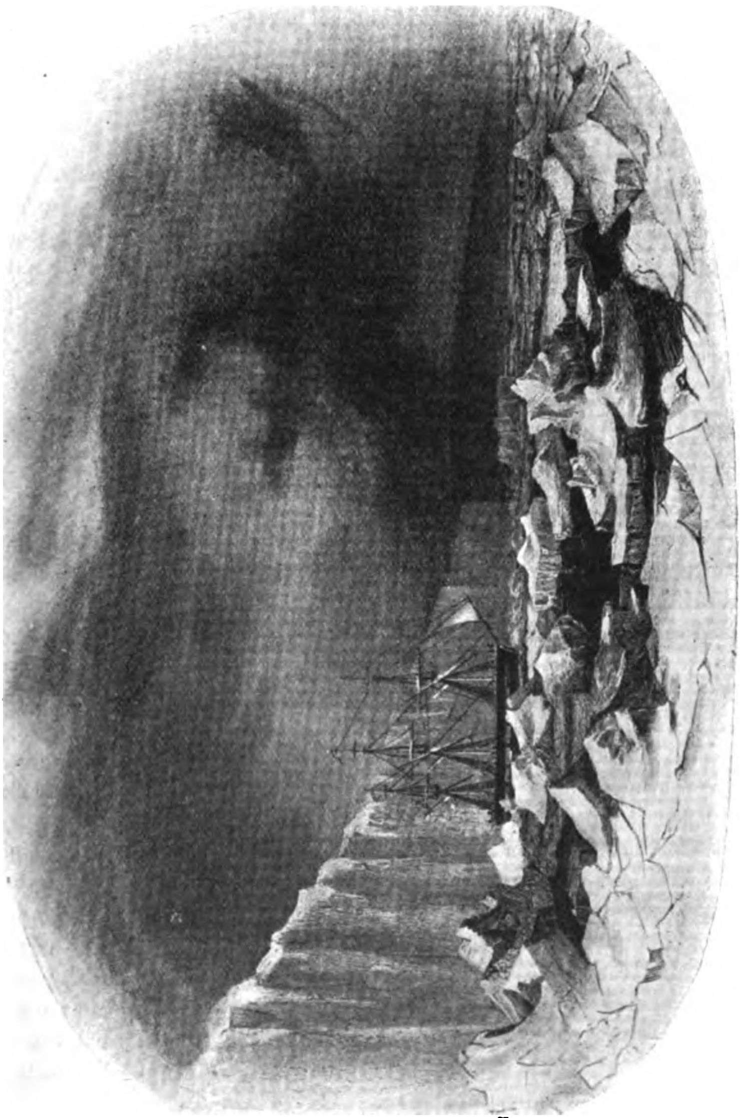
The first effect of this blow was to carry away the spanker-boom, the larboard stern-davit, and to crush the stern-boat. The starboard stern-davit was the next to receive the shock, and as this is connected with the spar-deck bulwarks the whole of them were started; the knee, a rotten one, which bound the davit to the taffrail, was broken off, and with it all the stanchions to the plank-sheer as far as the gangway.

Severe as was this shock, it happened fortunately that it was followed by as great a rebound. This gave the vessel a cant to starboard, and by the timely aid of the jib and other sails, carried her clear of the ice-island, and forced her into a small opening. While doing this, and before the vessel had moved half her length, an impending mass of ice and snow fell in her wake. Had this fallen only a few seconds earlier it must have crushed the vessel to atoms.

It was also fortunate that the place where she struck the ice-island was near its southern end, so that there was but a short distance to be

passed before she was entirely clear of it. This gave more room for the drifting ice, and permitted the vessel to be worked by her sails.

The relief from this pressing danger, however gratifying, gave no



'PEACOCK' IN CONTACT WITH ICEBERG.

assurance of ultimate safety; the weather had an unusually stormy appearance, and the destruction of the vessel seemed almost inevitable, with the loss of every life on board. They had the melancholy alter-

native in prospect of being frozen to death, one after the other, or perishing in a body by the dissolving of the iceberg on which they should take refuge should the vessel sink.

When the dinner hour arrived the vessel was again fast in the ice, and nothing could for a time be done: it was therefore piped as usual. This served to divert the minds of the men from the dangers around them.

When the meal was over the former manœuvring was resorted to, the yards being kept swinging to and fro in order to keep the ship's head in the required direction. She was labouring in the swell, with ice grinding and thumping against her on all sides; every moment something either fore or aft was carried away—chains, bolts, bobstays, bowsprit shrouds; even the anchors were lifted, coming down with a surge that carried away the eyebolts and lashings, and left them to hang by the stoppers. The cut-water also was injured, and every timber seemed to groan.

Similar dangers attended those in the boats. Passed Midshipman Eld was sent to plant the ice-anchors; there was no room for the use of oars; the grinding and grating of the ice, as it rose and fell with the swell, rendered great precaution necessary to prevent the boat from being swamped or crushed; and when it is stated that two hours of hard exertion were required to plant the ice-anchors, some idea of the difficulty attending this service will be had. But this was not all; the difficulty of returning was equally great, and no possible way of effecting it seemed to suggest itself; the sides of the icebergs could not be ascended, and to approach the berg on the side next the ship was certain destruction to the boat and crew, for the ice and water were foaming like a caldron; and to abandon the former was equally out of the question. At last a chance offered (although almost a hopeless one), by passing between two of these bergs that appeared on the other side of a small clear space. The boat was upon a small piece of ice, from which, by great exertions, she was launched; a few pulls at the oars brought them to the passage; the bergs were closing fast, and agitated by the swell; no time, therefore, was to be lost; the danger was already great, and in a few seconds it would be impossible to pass. They entered; their oars caught, and they got but halfway through when the icebergs closed in upon them and pressed the gunwales together, so as almost to crush the boat; the water entered her, and she was near sinking; when the berg stopped, retreated, and by another hard shove they went through, and were soon alongside the ship.

Every exertion was now made to work the ship and avoid heavy thumps from the ice. The mode resorted to, to get the ship about, was a novel one, namely, by urging her lee-bow against a piece of ice, which had the same effect as giving her a lee-helm; but this was found rather too expensive a mode of effecting the object, and on the pumps showing

an increase of water it was discontinued. The ice had been rapidly accumulating around the ship, contracting still more narrowly the space or area in which they were, and rendering their situation more hazardous.

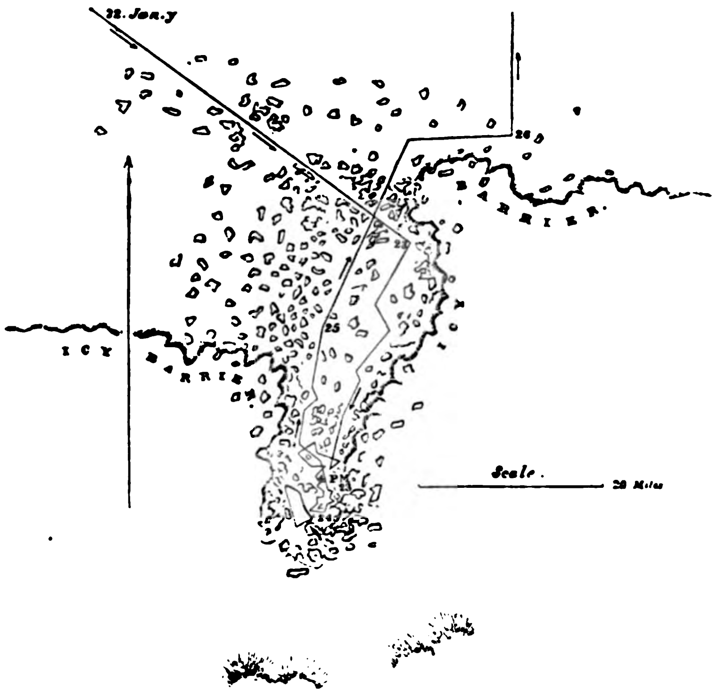
At 4 p.m. they clewed up the topsails, the ship being fast in the ice, with the wind directly in from the seaward. The ice-anchors were now again run out in hopes of relieving her from some of the strain; a short time afterwards the ice clearing from the stern enabled them to unship the rudder, which was taken on board in two pieces; it was immediately placed on the quarter-deck and all the carpenters employed on it.

It soon began to snow violently, and no clear sea could be seen from the ship in any direction. It becoming dark, the chance was that they would have to take up their last abode there. About six o'clock the weather cleared a little and the wind freshened; they parted the hawser attached to the ice-anchor, and made sail again for the clear sea, which could now be seen from the masthead. Towards 8 p.m., as if to blast the little hope that the continuance of clear weather inspired, the ship took a wrong cant, and was forced into a small opening leading farther into the ice to leeward, and towards the massive walls of the berg. Great exertions were made, and fortunately, by the aid of the ice-anchors and sails, they succeeded in getting her round, and her head again pointed towards the clear sea; but they were shortly afterwards wedged in between two large masses of ice. At midnight the sea was observed to rise, although the wind had not increased, causing much motion among the ice; and the stormy appearance of the sky continued, and gave promise of a gale. The only hope left was to force the ship through, and every means were employed to effect this object. The ice they had now to contend with was of larger dimensions, and the increased sea rendered it doubly dangerous. Some of the shocks against it were so heavy as to excite fears that the ship's bows would be driven in, and on one occasion three of the chronometers were thrown out of their beds of sawdust upon their sides. They continued to make but little headway, and the grinding and thumping on the ship was most painful. The hope of extricating her lessened every moment, for the quantity of ice between them and the sea was increasing, and the ship evidently moved with it to leeward. Few situations could be more trying, but the emergency was met by Captain Hudson with a coolness, perseverance, and presence of mind which secured the admiration of all who were present, and inspired full confidence and a firm reliance in his ability to overcome every difficulty that lay within the power of human means.

In the afternoon of the 25th the sea continued to increase, and the ship frequently struck against the masses of ice, while every foot they forged ahead carried them seemingly into a more precarious situation. At about 3 p.m. they found that the gripe had been beaten off, and they were now bruising up the stem and grinding away the bows. There

appeared no other course but to drive her out, which was deemed the only chance of saving the ship and crew. All the canvas that would draw was therefore set to force her through; and the wind favouring them, they had by four o'clock succeeded in passing the thick and solid ice, and shortly afterwards found themselves in clear water, without a rudder, the gripe gone, and, as was afterwards found, the stem ground down to within an inch and a half of the wood ends.

The annexed sketch of the bay will exhibit the situation of the



PEACOCK BAY.

ship more accurately; it is situated in latitude 65° 55′ 20″ S., longitude 151° 18′ 45″ E.

The carpenters were still employed on the rudder, and had succeeded in removing the broken pieces of the pintles from the second and third braces on the stern-post; the upper and lower pintles were broken, leaving only two to hang the rudder by. The weather seemed now to favour them, and about ten o'clock they had finished the rudder, which had been repaired in the best possible manner. Great credit is due to Mr. Dibble, the carpenter (who left his sick bed on the occasion), for his exertions, attention, and perseverance. He and the carpenter's crew worked twenty-four hours without intermission. The ship was now hove-to, for it was apprehended that her rolling would render the task

of shipping the rudder troublesome. By meridian, they were again in a situation to make sail to extricate themselves from a bay some thirty miles in extent, which, with the exception of the small opening by which they had entered, was apparently closed by the barrier.

Shortly afterwards, the wind becoming fair, they made all sail for the outlet. The weather proved fine and the winds moderate. At midnight they found the only opening left, which was not more than a quarter of a mile wide; they succeeded in passing through this, by 2 a.m., in a snow-storm, and felt grateful to God for their providential escape.

Captain Hudson now came to the conclusion of returning north. "After," as he says, "thoroughly turning over in my own mind the state of the ship—with the head of the rudder gone, hanging by two braces, and in such a state that we could hardly hope to make it answer its purposes again, in encountering the boisterous weather we should have to pass through before reaching the first port; the ship considerably strained; her starboard spar-deck bulwarks gone as far forward as the gangway; the gripe off, and the stern mutilated—fully satisfied from this state of things that she was perfectly useless for cruising among icebergs, and the accompanying dangers, in thick, foggy weather, to which, in these latitudes, we should be more or less subject, and where rapid evolutions were often necessary, in which the rudder must perform its part; and that the ship would require extensive repairs before being employed in surveying operations; and feeling that the season was rapidly coming round when our services would be required in that duty, I held a council of the ward-room officers, and required their opinions as to making any further attempts to cruise in these latitudes.

"There was but one opinion as to the necessity of the ship's returning north, with the exception of Mr. Emmons and Mr. Baldwin, who thought the rudder might stand, provided we did not get near the ice or fall in with icebergs. This, of course, would be to effect little or nothing, and result only in a loss of time. I accordingly put the ship's head north, determined to proceed at once to Sydney to effect the necessary repairs, so as to be ready at the earliest possible day to join the squadron."

Such were the dangers and difficulties from which the *Peacock*, by the admirable conduct of her officers and crew, directed by the consummate seamanship of her commander, was enabled at this time to escape. There still, however, remained thousands of miles of a stormy ocean to be encountered, with a ship so crippled as to be hardly capable of working, and injured to such an extent in her hull as to be kept afloat with difficulty. The events of this perilous navigation must, however, be postponed, until I shall have given the narrative of the proceedings of the other vessels of the squadron, while tracing out the position of the icy barrier and following along the newly discovered continent.

CHAPTER X.

Antarctic Cruise—*continued.*

1840.

Proceedings of the *Vincennes* from the 22nd of January—Disappointment Bay—Watering on the ice—Diagrams of the ice-islands—Their utility—Violent gale and snow-storm—Narrow escape from striking the ice—The open sea reached—Return of fine weather—*Vincennes* stands again to the south and reaches the icy barrier—Piner's Bay—Soundings in 30 fathoms—Another violent gale—Report of the medical officers—Opinion of the ward-room officers—Determination to proceed with the cruise—The events up to the 14th of February—Landing on an iceberg—Specimens of rocks obtained—Inquiry in relation to the formation of icebergs—Their separation from the land—Their progress—Further evidence in relation to the Antarctic continent—Estimate of the rate at which the floating ice moves—The *Vincennes* begins her return to the north.

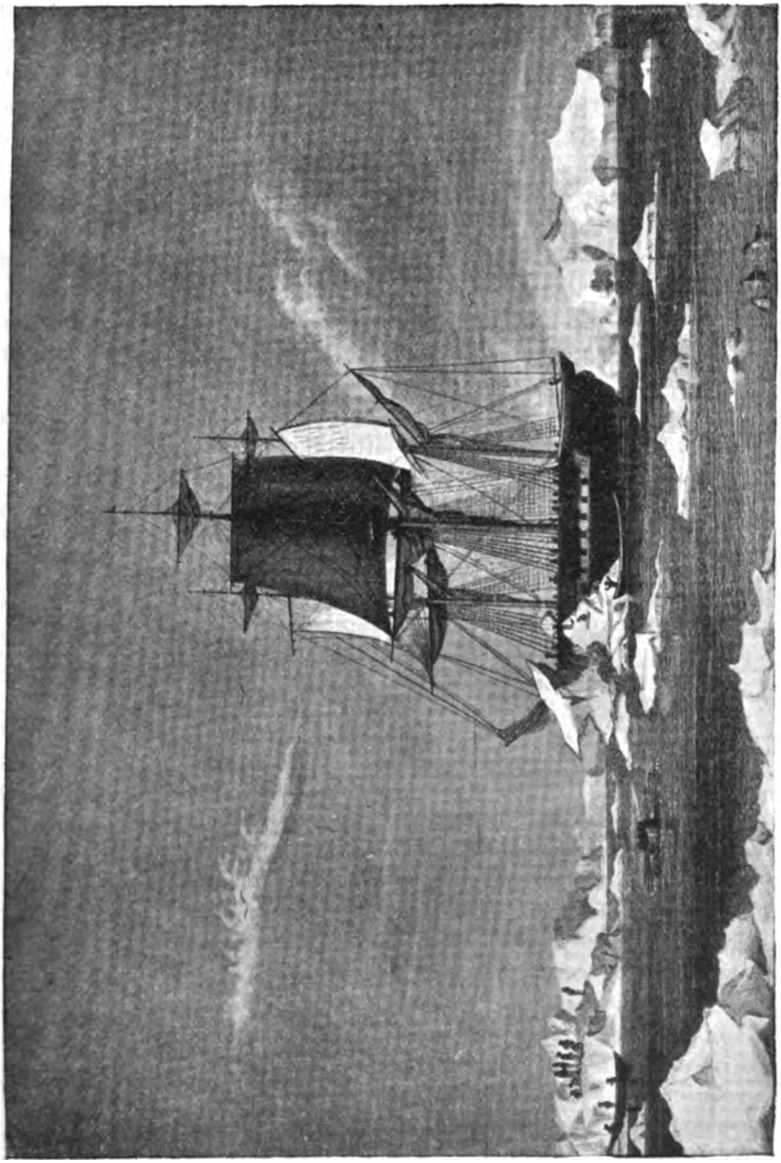
In taking up the narrative of the disaster sustained by the *Peacock*, with which the preceding chapter closes, the *Vincennes* and *Porpoise* were left on the 22nd of January. On that day the *Vincennes* passed the place through which the *Peacock* entered, as has been related, on the 23rd, and found no opening. To judge from the manner in which the ice moved during the time the *Peacock* was enclosed in it, I am inclined to ascribe the alternate opening and closing of the passage into the bay to a tide setting along this coast. In support of this opinion it is sufficient to state that the strength of the winds experienced on board that vessel was at no time sufficient to account for the manner in which the ice was found to move.

About 30 miles to the westward of this point the *Vincennes* passed a remarkable collection of tabular icebergs, for whose existence I can account in no other manner than by supposing them to be attached to a rocky islet, which formed a nucleus, to which they adhered. It was quite obvious that they had not been formed in the place where they were seen, and must, therefore, have grounded after being adrift.

On the 23rd of January, after passing around this group of icebergs, the sea was found comparatively clear, and a large open space showed itself to the southward. Into this space the course of the *Vincennes* was immediately directed. While thus steering to the south, the appearance of land was observed on either hand, both to the eastward and westward.

Pursuing this course, we by midnight reached the solid barrier, and all approach to the land on the east and west was entirely cut off by the close packing of the icebergs. I was therefore reluctantly compelled to return, not a little vexed that we were again foiled in our endeavour to reach the Antarctic continent. This was a deep indentation in the coast, about 25 miles wide; we explored it to the depth of about 15 miles, and

did not reach its termination. This bay I have called Disappointment Bay; it is in latitude 67° 04′ 30″ S., longitude 147° 30′ E. The weather



'VINCENNES' IN DISAPPOINTMENT BAY.

was remarkably fine, with a bracing air; the thermometer in the air 22°, in the water 31°.

The nex day, 24th, we stood out of the bay, and continued our

course to the westward. About noon, to my surprise, I learnt that one of the officers, Lieutenant Underwood, had marked on the log-slate that there was an opening of clear water, subtending three points of the compass, at the bottom of Disappointment Bay. Though confident that this was not the fact, in order to put this matter at rest, I at once determined to return, although 40 miles distant, and ordered the ship about, to refute the assertion by the officer's own testimony. This was most effectually done the next morning, 25th, when the ship reached the identical spot, and all were fully convinced that no opening existed. The whole bay was enclosed by a firm barrier of ice from north-north-west to east-north-east.

The weather proved delightful, with light airs from the southward, and I determined to take this opportunity to fill up the water-tanks with ice. The ship was hove-to, a hawser got in readiness, the boats lowered and brought alongside of an iceberg well adapted to our purpose.

The same opportunity was also taken to make the magnetic observations on the ice, and to try the local attraction of the ship.

Many birds were seen about the ship, of which we were fortunate in obtaining specimens. The day was remarkably clear, and the same appearance of land was seen that had been witnessed on the 24th. We filled nineteen of our tanks with ice, after having allowed it to remain for some time on deck for the salt water to drain off in part, and it proved very potable.

The view of the ship in this position will give an idea of her situation.

At about 5 p.m. we had completed our required store of ice, and cast off, making sail to the northward.

In order that no further mistakes should take place as to the openings being passed, I issued an order, directing the officer of the deck on being relieved to go to the masthead and report to me the exact situation of the ice; and this was continued during the remainder of our cruise among it.

In threading our way through the many icebergs, it occurred to me that they might be considered as islands, and a rough survey made of them, by taking their bearings at certain periods and making diagrams of their positions. This was accordingly done, and every few hours they were inserted on the chart which I was constructing in my progress.

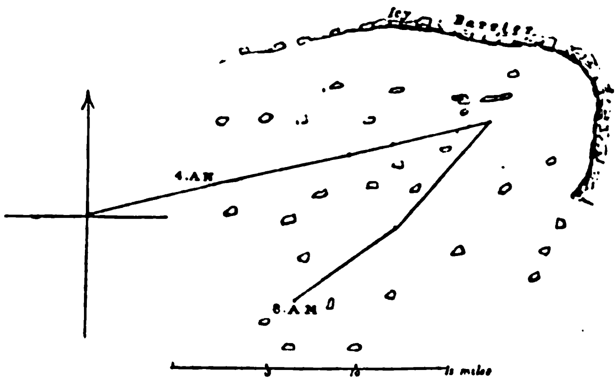
[One of the diagrams is given in the next page.]

This I found to be very useful, and it gave me confidence in proceeding, for I had a tolerable chart to retreat by in case of need, at least for a few hours, during which time I had reason to believe that there was not much probability of the icebergs changing their relative positions.

The dip observed on the ice was 87° 30′, and the variation 12° 46′

easterly. The compasses were found to be very sluggish, having but little horizontal directive force.

About half an hour after we cast off from the iceberg, a thick snow-storm came up with the wind from the south-east. Although there were very many ice-islands around us on our way out, I felt that I understood



the ground well, having passed over it twice, and, knowing I had a space of a few miles only thinly sprinkled with icebergs, I hove-to with shortened sail. This was the first south-east wind we had had since being on this coast; I had been disappointed in not finding it from that quarter before; for I had been informed by those who had navigated in high southern latitudes that south-east would be the prevailing wind, and would be attended with fine weather. Now, however, with a fair wind, I was unable to run, for the weather was unfavourable.

At 6 a.m. on the 26th we again made sail, and at 8 a.m. we discovered the *Porpoise*, to whom we made signals to come within hail. We found them all well, and compared chronometers.

As it still blew fresh from the south-east, and the weather became a little more clear, we both bore away, running through much drift-ice, at the rate of nine knots an hour. We had the barrier in sight; it was, however, too thick to see much beyond it. Sailing in this way I felt to be extremely hazardous, but our time was so short for the examination of this icy coast, that while the barrier was to be seen I deemed it my duty to proceed. We, fortunately, by good look-outs, and carefully conning the ship, were enabled to avoid any heavy thumps.

On the 27th we again had the wind from south-south-west. The floe-ice had become so thick that we found it impossible to get through it in the direction I wished to go, and we were compelled to pass round it. The *Porpoise* was in sight until noon. The weather proved beautifully clear. A long range of tabular icebergs was in sight to the southward, indicating, as I have before observed, that the coast was near. I passed through these, losing sight of the *Porpoise* to the north-west, about noon,

when we were in longitude 142° 40′ E., latitude 65° 54′ 21″ S., variation 5° 08′ easterly.

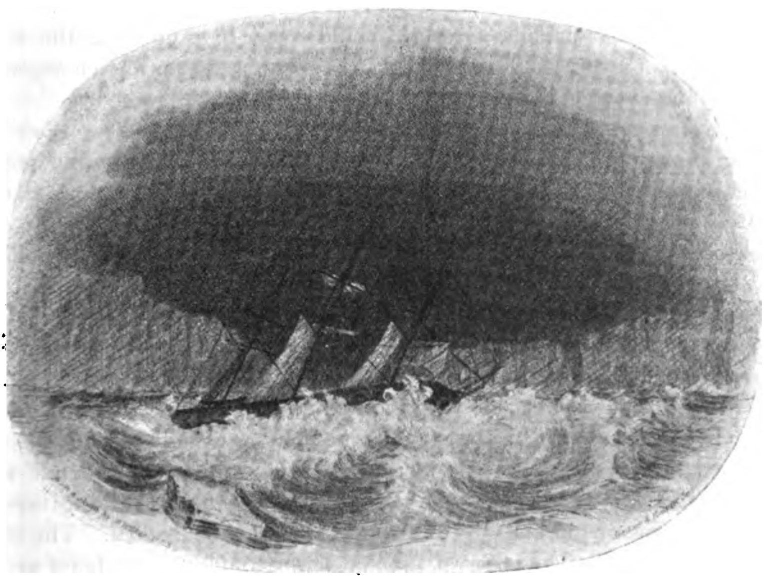
On the 28th I found myself completely surrounded by the tabular icebergs, through which we continued to pass. Towards midnight the wind shifted to the south-east, and enabled me to haul more to the southward. At 9.30 a.m. we had another sight of the land ahead, and every prospect of nearing it with a fine breeze. The sight of the icebergs around us, all of large dimensions, was beautiful. The greatest number in sight at one time was noted, and found to be more than a hundred, varying from a quarter of a mile to three miles in length. We took the most open route, and by eleven o'clock had run upwards of forty miles through them. We had the land now in plain view, but the weather soon began to thicken and the breeze to freshen. At noon it was so thick that every thing was hidden, and no observation was obtained. The ship was hove-to, but shortly after again put under way, making several tacks to keep my position, which I felt was becoming a critical one, in case a gale should ensue. I therefore looked carefully over my chart, and was surprised at the vast number of icebergs that appeared on it. At 2 p.m. the barometer began to fall and the weather to change for the worse. At 5 p.m. a gale was evidently coming on, so we took three reefs in the topsails. It appeared now that certain wreck would ensue should we remain where we were; and after much consideration I made up my mind to retrace my way and seek the open space forty miles distant, taking for a landmark a remarkable berg that had been the last entered on the chart, and which would be a guide to my course out. I therefore stood for its position. The weather was so thick that it was necessary to run close to it to be quite sure of recognising it, for on this seemed to depend our safety. About the estimated time we would take to pass over the distance, an iceberg was made (we were within 1000 feet of it) which, at first view, I felt confident was the one sought, but was not altogether satisfied afterwards.

I therefore again consulted my chart, and became more doubtful of it. Just at that moment I was called on deck by an officer, who informed me that there were icebergs a short distance ahead.

Such proved to be the case; our path was beset with them, and it was evident we could not regain our route. To return was worse, so having but little choice left I determined to keep on. To encounter these icebergs so soon after seeing the other was in some respects satisfactory, for it removed all doubts, and showed me that we were not near the track by which we entered. Nothing, therefore, was to be done but to keep a good look-out, and the ship under sufficient way to steer well; my safest plan was to keep as near our former track as possible, believing it to be most free of these masses.

At 8 p.m. it began to blow very hard, with a violent snowstorm, circumscribing our view, and rendering it impossible to see more than

two ship's-lengths ahead. The cold was severe, and every spray that touched the ship was immediately converted into ice. At 9 p.m., the barometer still falling and the gale increasing, we reduced sail to close-reefed fore and main-topsails, reefed foresail, and trysails, under which we passed numerous icebergs, some to windward and some to leeward of us. At 10.30 we found ourselves thickly beset with them, and had many narrow escapes; the excitement became intense; it required a constant change of helm to avoid those close aboard; and we were compelled to press the ship with canvass in order to escape them, by keeping her to windward. We thus passed close along their weather sides, and distinctly heard the roar of the surf dashing against them. We had,



'VINCENNES' AMONGST ICEBERGS.

from time to time, glimpses of their obscure outline, appearing as though immediately above us. After many escapes, I found the ship so covered with ice and the watch so powerless in managing her, that a little after midnight on the 29th I had all hands called. Scarcely had they been reported on deck, when it was made known to me that the gunner Mr. Williamson had fallen, broken his ribs, and otherwise injured himself, on the icy deck.

The gale at this moment was awful: we found we were passing large masses of drift-ice, and ice-islands became more numerous. At a little after one o'clock it was terrific, and the sea was now so heavy that I was obliged to reduce sail still further; the fore and main-topsails

were clewed up; the former was furled, but the latter being a new sail, much difficulty was found in securing it.

A seaman, by the name of Brooks, in endeavouring to execute the order to furl, got on the lee-yardarm, and the sail having blown over the yard, prevented his return. Not being aware of his position until it was reported to me from the forecastle, he remained there some time. On my seeing him he appeared stiff, and clinging to the yard and lift. Spilling lines were at once rove, and an officer with several men sent aloft to rescue him, which they succeeded in doing by passing a bowline around his body and dragging him into the top. He was almost frozen to death. Several of the best men were completely exhausted with cold, fatigue, and excitement, and were sent below. This added to our anxieties, and but little hope remained to me of escaping: I felt that neither prudence nor foresight could avail in protecting the ship and crew. All that could be done was to be prepared for any emergency by keeping every one at his station.

We were swiftly dashing on, for I felt it necessary to keep the ship under rapid way through the water, to enable her to steer and work quickly. Suddenly many voices cried out, "Ice ahead!" then, "On the weather bow!" and again, "On the lee-bow and abeam!" All hope of escape seemed in a moment to vanish; return we could not, as large ice-islands had just been passed to leeward: so we dashed on, expecting every moment the crash; the ship in an instant, from having her lee guns under water, rose upright; and so close were we passing to leeward of one of these huge islands, that our trysails were almost thrown back by the eddy wind; the helm was put up to pay the ship off, but the proximity of those under our lee bade me keep my course. All was now still except the distant roar of the wild storm that was raging behind, before, and above us; the sea was in great agitation, and both officers and men were in the highest degree excited. The ship continued her way, and as we proceeded a glimmering of hope arose, for we accidentally had hit upon a clear passage between two large ice-islands, which in fine weather we should not dare to have ventured through. The suspense endured while making our way between them was intense, but of short duration; and my spirits rose as I heard the whistling of the gale grow louder and louder before us, as we emerged from the passage. We had escaped an awful death, and were again tempest-tost.

We encountered many similar dangers that night; at 4.30 a.m. I found we had reached the small open space laid down on my chart, and at 5 o'clock I hove-to the ship. I had been under intense excitement, and had not been off the deck for nine hours, and was now thankful to the Providence that had guided, watched over, and preserved us. Until 7 a.m. all hands were on deck: when there was some appearance of the weather moderating they were piped down.

The barometer was marked at intervals, for which the reader is referred to Appendix XXVI.

This gale was from the south-east, from which quarter it blew during the whole of its strength; and when it began to moderate the wind veered to the southward; by noon we felt satisfied that the gale was over and that we had escaped, although it was difficult to realise a sense of security when the perils we had just passed through were so fresh in our minds, and others still impending. Towards 4 o'clock it cleared off, and we saw but few icebergs near us. Our longitude was found to be 140° E., latitude 63° 30′ S., and I again made sail for the ice to the south, to pass over the very route we had just traversed through so many perils.

The wind had now hauled to the south-west; at 6 p.m. we again began to enter among ice-islands. The weather appeared settled, but I had so often been deceived by its fickleness that I felt no reliance ought to be put in its continuance. A powerful inducement was held out to us, in the prospect of getting close enough to effect a landing; and this rendered us insensible to the dangers.

On the morning of the 30th the sun rose in great brilliancy, and the scene could hardly be realised as the same as that we had passed through only twenty-four hours before. All was now quiet; a brisk breeze blew from the eastward, all sail was set, and there was every prospect that we might accomplish our object, for the land was in sight, and the icebergs seemed floating in quiet. We wound our way through them in a sea so smooth that a yawl might have passed over it in safety. No straight line could have been drawn from us in any direction that would not have cut a dozen icebergs in the same number of miles, and the wondering exclamations of the officers and crew were oft repeated, "How could we have passed through them unharmed?" and "What a lucky ship!" At 8 o'clock we had reached the icy barrier, and hove-to close to it. It was tantalising with the land in sight to be again and again blocked out. Open water was seen near the land to the south-west of us, and a tortuous channel through the broken ice to leeward, apparently leading to it. All sail was immediately crowded; we passed rapidly through, and found ourselves again in clear water which reached to the shores; the barrier extending in a line with our course about two miles to windward, and a clear channel to the north-west about two miles wide as far as the eye could reach. Seeing this, I remarked to one of the officers that it would have been a good place to drift in during the last gale, little thinking that in a few short hours it would serve us for that purpose in still greater need. A brisk gale ensued, and the ship ran at the rate of nine or ten miles an hour; one reef was taken in the topsails, and we stood directly in for the most southerly part of the bay.

This bay was formed partly by rocks and partly by ice-islands. The

latter were aground, and on the western side of the bay extended about five miles to the northward of our position.

While we stood on in this direction the gale increased, and our room became so circumscribed that we had not time on any one tack to reduce our canvass before it became necessary to go about. In this way we approached within half a mile of the dark volcanic rocks, which appeared on both sides of us, and saw the land gradually rising beyond the ice to the height of 3000 feet, and entirely covered with snow. It could be distinctly seen extending to the east and west of our position fully 60 miles. I make this bay in longitude 140° 02′ 30″ E., latitude 66° 45′ S.; and, now that all were convinced of its existence, I gave the land the name of the Antarctic Continent. Some of the officers pointed out the appearance of smoke, as if from a volcano, but I was of opinion that this was nothing but the snow-drift caused by the heavy squalls. There was too much wind at this time to tack; I therefore had recourse to luffing the vessel up in the wind, and wore her short round on her heel. At the same time we sounded, and found a hard bottom at the depth of no more than 30 fathoms. I made a rough sketch of this bay, which I have called Piner's Bay, after the signal-quartermaster of that name. It was impossible to lower a boat or to remain longer; indeed, I felt it imperative on me to clear its confined space before the floating ice might close it up.

At 10.30 we had gone round, and in an hour more we cleared the bay. At noon the wind had increased to a gale, and by 1 o'clock p.m. we were reduced to storm-sails, with our top-gallant yards on deck. The barometer had again declined rapidly, proving a true indicator, but giving little or no warning. To run the gauntlet again among the icebergs was out of the question, for a large quantity of field-ice would have to be passed through, which must have done us considerable damage, if it did not entirely disable us. The clear space we occupied was retained until 5 or 6 o'clock, when I found the floe-ice was coming down upon us; I then determined to lay the ship for a fair drift through the channel I had observed in the morning, and which I had every reason to believe, from the wind (south-east) blowing directly through it, would not be obstructed until the floe-ice came down. It was a consolation to know that if we were compelled to drift, we should do so faster than the ice; I therefore thought it as well to avoid it as long as possible. Another reason determined me to delay the drifting to the latest moment. I did not believe that the extent of the channel we had seen in the morning was more than 10 miles in extent, and at the rate we drifted the end of it would be reached long before the gale was over. This, like the former gale, was an old-fashioned snow-storm. All the canvass we could show to it at one time was a close-reefed main-topsail and fore-storm-staysail. It blew tremendously, and the sea we experienced was a short, disagreeable one, but nothing to be compared to

that which accompanied the first gale. From the shortness of the sea I inferred that we had some current. This state of things continued for several hours, during which we every moment expected to reach the end of our channel. Since the last gale the whole crew, officers and men, had been put in watch and watch, ready for an instantaneous call, and prepared for rapid movements. The snow was of the same sleety or cutting character as that of the previous day, and seemed as if armed with sharp icicles or needles.

The 31st brought no moderation of the weather. At 1 a.m. a group of ice-islands was reported, and shortly afterwards field-ice close under our lee.

We wore ship instantly, and just avoided coming in contact with the latter; sail was immediately made on the ship, and the scene of the former gale again gone through (which it is needless here to repeat), with this exception, that we were now passing to and fro among icebergs immediately to windward of the barrier, and each tack brought us nearer to it. Between 4 and 5 a.m. our space was becoming confined, and there was no abatement of the gale; I therefore, as it had cleared sufficiently to enable us to see a quarter of a mile, determined to bear up and run off north-north-west for a clear sea. In doing this we passed icebergs of all dimensions and heavy floe-ice. By 8.30 we had run thirty miles, when, finding a more open sea, I judged we had partially cleared the ice. At noon the gale still continued. The lowest reading of the barometer during this gale was 28·59 in.

After lasting thirty hours the gale, at 6 p.m., began to moderate a little, when we again made sail to the southward. I now felt inclined to seek Piner's Bay again, in order to effect a landing. This would have been a great personal gratification; but the bay was sixty miles distant, so that to revisit it would occupy time that was now precious; and feeling satisfied that a great extent of land wholly unknown lay to the westward, I deemed it my duty to proceed to its discovery, not doubting that if my opinions of its existence were correct, a place equally feasible for landing would be found. Another subject also presented itself, which, for a time, caused me some anxiety, and which I confess was not only unexpected by me, but directly at variance with my own observations on the condition of my crew. As I feel compelled to give a complete detail of our proceedings, I must now revert to this subject.

The following report of the medical officers of the ship was made to me on the day of its date.

"U.S. Ship *Vincennes*,
At Sea, January 31st, 1840.

"Sir,—It becomes our duty, as medical officers of this ship, to report to you in writing the condition of the crew at the present time.

"The number upon the list this morning is fifteen; most of these

cases are consequent upon the extreme hardships and exposure they have undergone during the last gales of wind, when the ship has been surrounded with ice.

"This number is not large, but it is necessary to state that the general health of the crew, in our opinion, is decidedly affected, and that under ordinary circumstances the list would be very much increased, while the men under the present exigencies, actuated by a laudable desire to do their duty to the last, refrain from presenting themselves as applicants for the list.

"Under these circumstances we feel ourselves obliged to report that, in our opinion, a few days more of such exposure as they have already undergone, would reduce the number of the crew by sickness to such an extent as to hazard the safety of the ship and the lives of all on board.

"Very respectfully, your obedient servants,

(Signed) J. L. Fox,
Assistant Surgeon.
T. S. Whittle,
Assistant Surgeon.

"To Charles Wilkes, Esq.,
Commanding Exploring Expedition."

Although my own opinion, as I have stated, differed from that expressed in the report, I deemed it my duty to ask the opinion of the ward-room officers, and also, in order to procure additional medical advice, restored to duty Acting-Surgeon Gilchrist, who was under suspension. The opinion of the ward-room officers was asked in a written circular, of which the following is a copy.

"U.S. Ship *Vincennes*,
At Sea, January 31st, 1840.

"Gentlemen,—The receipt of the enclosed report of Drs. Fox and Whittle, relative to the health and condition of the crew of this ship at this time, renders it necessary for me to decide whether it is expedient to push farther south in exploration under the present circumstances.

"As you are acquainted with all the circumstances, it is unnecessary to repeat them, except to remark that your opinion is requested before I decide upon the course to be pursued, in consequence of the strong bias self-interest might give me in the prosecution of our arduous duties. I wish the report returned to me, and for you to communicate your opinion in writing.

"I am, respectfully, etc.,
Charles Wilkes,
Commanding Exploring Expedition.

"To the Ward-Room Officers,
U.S. Ship *Vincennes.*"

The answers to this letter will be seen in Appendix XXVII.; and it is sufficient here to say that a majority concurred in opinion with the report of the medical officers. Notwithstanding these opinions, I was not satisfied that there was sufficient cause to change my original determination of passing along to the appointed rendezvous, and after full consideration of the matter I came to the conclusion, at whatever hazard to ship and crew, that it was my duty to proceed, and not give up the cruise until the ship should be totally disabled, or it should be evident to all that it was impossible to persist any longer. In bringing myself to this decision, I believe that I viewed the case on all sides with fairness, and allowed my duty to my country, my care for those whom it had committed to my charge, and my responsibility to the world, each to have its due weight.

The weather now moderated, and I ordered sail to be made. The 2nd of February found us about sixty miles to the westward of Piner's Bay, steering to the southward, and as usual, among ice-islands, with the land in sight. The land had the same lofty appearance as before. We stood in until 3 p.m., when we were within two and a-half miles of the icy cliffs by which the land was bounded on all sides. These were from 150 to 200 feet in height, quite perpendicular, and there was no appearance whatever of rocks; all was covered with ice and snow. A short distance from us to the westward was a long range of icebergs aground, which, contrary to the usual appearance, looked much weather-beaten. We tried for soundings, but did not get any with 150 fathoms, although the water was much discoloured. The badness of the deep-sea line was a great annoyance to us, for deeper soundings would probably have obtained bottom. No break in the icy barrier, where a foot could be set on the rocks, was observable from aloft. The land still trended to the westward as far as the eye could reach, and continued to exhibit the same character as before. Our longitude now was 137° 02′ E., latitude 66° 12′ S.; we found the magnetic declination westerly.

This proved a fine day, so that we had an opportunity of airing the men's bedding, of ventilating the ship, and of getting rid of the ice with which we were much encumbered. The thermometer varied from 33° to 36°. Our sick-list had increased the last few days to twenty; many of the men were affected with boils, which rendered them comparatively useless; and ulcers, which were caused by the least scratch, were exceedingly prevalent; but their food was good, they had plenty of it, and their spirits were excellent. The high land was seen this afternoon, but the barrier along which we were passing prevented any nearer approach. This evening it was perceptible that the days were becoming shorter, which was a new source of anxiety, for we were often surrounded by numerous ice-islands, which the darkness rendered more dangerous.

Towards evening the weather became unsettled, and the 3rd of

February was ushered in by another gale, accompanied with snow. The barometer fell lower than heretofore, namely to 28·460 in.; the thermometer stood at 33°. Before the thick snow came on we had taken the bearings of the ice-islands, and finding we had a few miles comparatively free from them, I determined to await the result of the storm, and made everything snug to encounter it. The gale continued throughout the day, and although it moderated after 5 p.m. we had some strong squalls, but nothing so violent as those we had already experienced. The ship, in consequence of the snow, became more damp and uncomfortable, and our sick-list was increased to thirty, who were rather overcome by want of rest and fatigue than affected by any disease. To remedy the dampness a stove was placed on the gun-deck, and fires kept burning in the galleys on the berth-deck, more for the purpose of drying the men's clothes than for warmth. We had no observations this day, but the dead reckoning gave the longitude 134° E., latitude 63° 49′ S.

The 4th and 5th the weather continued the same; as the winds became lighter thick snow fell, and we were able to see only a short distance from the ship. We contrived by manœuvring to retain our position. On this last day we got a tolerable observation, which gave our longitude as 133° 42′ E., and latitude 64° 06′ S.

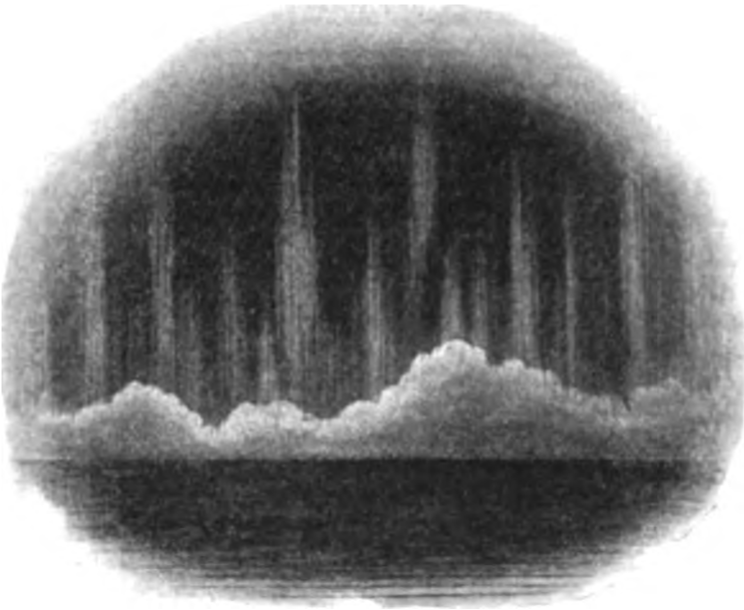
The first part of the 6th the same thick weather continued, but towards 4 p.m. it began to clear, when we again made sail, until we saw and took the bearings of the barrier. We found ourselves situated opposite the part of it we had seen three days before. It still had the appearance of being attached to the land and in one uninterrupted line. Wishing to examine it closely, I hove-to for broad daylight. Many whales, penguins, flocks of birds, and some seals were reported.

On the 7th we had much better weather, and continued all day running along the perpendicular icy barrier, about 150 feet in height. Beyond it the outline of the high land could be well distinguished. At 6 p m. we suddenly found the barrier trending to the southward, and the sea studded with icebergs. I now hauled off until daylight, in order to ascertain the trending of the land more exactly. I place this point, which I have named Cape Carr, after the first lieutenant of the *Vincennes*, in longitude 131° 40′ E., and latitude 64° 49′ S.

On the 8th, at daylight, we again made sail to the southward, and found at 4 a.m. the field of ice had stopped our progress, and the weather was thick. Land was no longer seen to the south, a deep bay apparently making in. We continued our course to the westward along the barrier until 8 p.m., when we were again brought-to. At 7 p.m. we had strong indications of land; the barrier was of the former perpendicular form, and later the outline of the continent appeared distinct, though distant. The night was dark and unpleasant. At noon our longitude was 127° 07′ E., and latitude 65° 03′ S.; variation 14° 30′ westerly.

On the 9th we had the finest day we had yet experienced on this

coast; the wind had veered from the east to south-west, and given us a clear, bracing, and wholesome atmosphere. The barrier exhibited the same appearance as yesterday. Our longitude was 125° 19′ E., latitude 65° 08′ S., variation 32° 45′ westerly. The current was tried, but none found; the pot was only visible at five fathoms; the colour of the water a dirty green; the dip sector gave 3′ 15″. I never saw a clearer horizon, or one better defined than we had to the northward. The icy barrier was really beautiful. At midnight we had a splendid display of the Aurora Australis, extending all around the northern horizon, from west-by-north to east-north-east.



AURORA AUSTRALIS.

Before its appearance, a few clouds only were seen in the south-east, on which the setting sun cast a red tint that barely rendered them visible. The horizon, with this exception, appeared clear and well defined. The spurs or brushes of light frequently reached the zenith, converging to a point near it.

Although no clouds could be seen in the direction of the aurora, before or after its appearance, yet, when it was first seen, there appeared clouds, of the form of massive cumuli, tinged with pale yellow, and behind them arose brilliant red, purple, orange, and yellow tints, streaming upwards in innumerable radiations, with all the shades that a combination of these colours could effect. In its most brilliant state

it lasted about twenty minutes. The gold-leaf electrometer was tried, but without being affected: the instrument, however, was not very sensitive. Being somewhat surprised at the vast mass of cumuli which appeared during the continuance of the aurora, I watched after its disappearance till daylight, but could see only a few clouds: I am, therefore, inclined to impute the phenomenon to some deception caused by the light of the aurora. The apparent altitude of these clouds was 8°.

On the 10th we were again favoured by the weather; it gave us a fine sunshine, and an opportunity of airing the ship and drying the clothes. All the sick were improving in health.

Running close along the barrier, which continued of the same character, although more broken than yesterday, we saw an appearance of land, although indistinctly, to the southward. The water was of the same colour here as before, and the wind being from the south-south-east we made some progress, and found ourselves in longitude 122° 35′ E., latitude 65° 27′ S.; the variation had now increased to 44° 30′ westerly. No aurora was seen this night, although it was looked for anxiously.

11th.—The barometer had been stationary at 29·080 in. for the last three days; it now began to fall; the temperature of the air was 31°, of the water 32°. The fall of the barometer was soon followed by snow and thick weather. The trending of the barrier had been south-west by west, and a good deal of floe-ice had been met with, which we ran through. The sea was quite smooth, and many icebergs were enclosed in the barrier, which was very compact and composed of flat fields. At 10 p.m. I found it too dark to run, and hove-to.

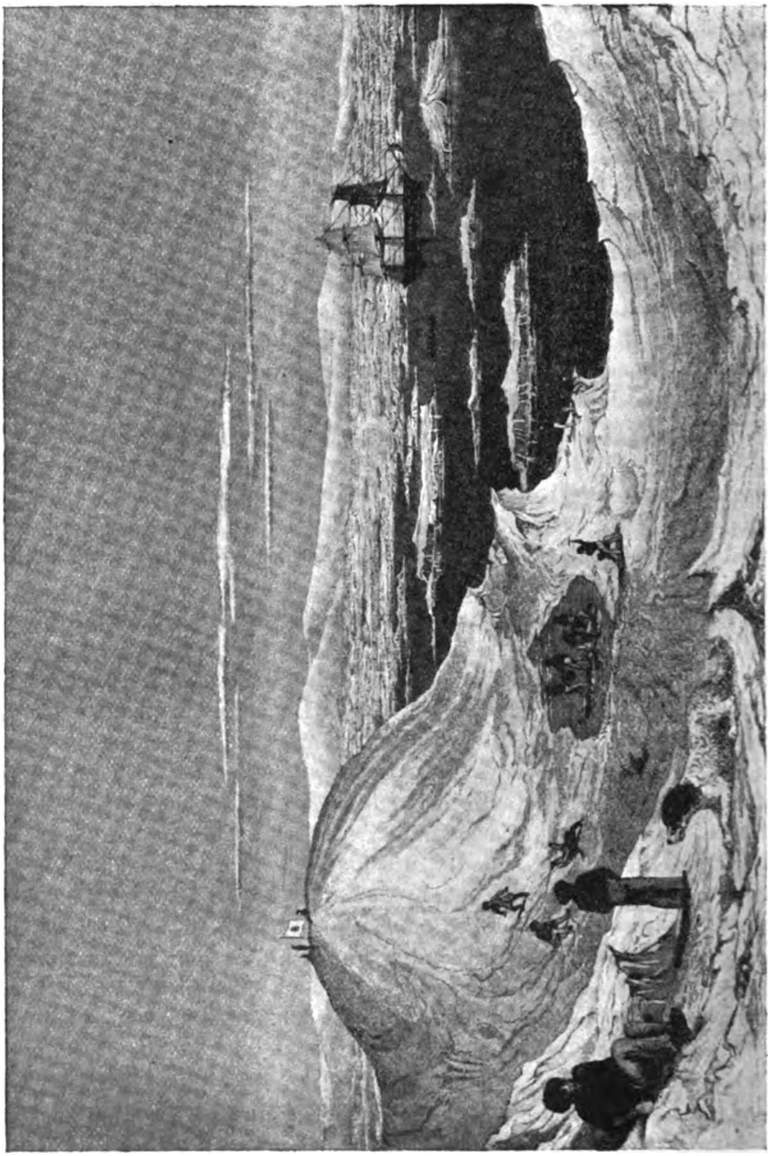
During the 12th we had pleasant weather, and at 2 a.m. filled away. At 8 a.m. land was reported to the south-west. Keeping along the barrier and increasing our latitude, I again had hopes of getting near the land. We passed through great quantities of floe-ice until 1 p.m., when the solid barrier prevented our farther progress. Land was now distinctly seen, from eighteen to twenty miles distant, bearing from south-south-east to south-west—a lofty mountain range, covered with snow, though showing many ridges and indentations. I laid the ship to for three hours, in hopes of discovering some opening or movement in the ice, but none was experienced. I tried the current, and found none. The water was of a dirty dark green. We sounded with the wire-line in 250 fathoms, and found no bottom. The temperature at that depth was 30½°, of the air 31°. The barrier had in places the appearance of being broken up, and we had decreased our longitude to 112° 16′ 12″ E., while our latitude was 64° 57′. This puts the land in about 65° 20′ S., and its trending nearly east and west. The line of the icy barrier was generally uniform, although it was occasionally pierced with deep bays. We saw some icebergs with decided spots of earth on them, which gave me hopes of yet obtaining the object of my wishes. The water was remarkably smooth during this day, and the

weather clear, enabling us to see a great distance. Two hours after we bore away we left the floe-ice, and entered a clear sea to the westward, where we lost sight of the barrier for a time; but in hauling up to the south-west it was, by 8 p.m., within three miles of us, when we again kept off parallel to its trending. The appearance of land still continued. Shortly after I hove-to, for the purpose of awaiting the daylight, to continue our observations of the land, with little prospect or probability of reaching it, from the immense quantity of ice which continued to form an impenetrable barrier.

13th.—At 2 a.m. we made sail to the south-west, in order to close with the barrier, which we found retreated in that direction, and gave us every prospect of getting nearer to it. Our course for the most part was through icebergs of tabular form. In the afternoon we had the land ahead, and stood in for it with a light breeze until 6.30 p.m., when I judged it to be ten or twelve miles distant. It was very distinct, and extended from west-south-west to south-south-east. We were now in longitude 106° 40′ E., and latitude 65° 57′ S.; the variation was 54° 30′ westerly. The water was very green. We sounded in 300 fathoms, and found no bottom. The weather having an unsettled appearance, we stood off to seek a clearer space for the night. The land left was high, rounded, and covered with snow, resembling that first discovered, and had the appearance of being bound by perpendicular icy cliffs.

14th.—At daylight we again made sail for the land, beating in for it until 11 a.m., when we found any further progress quite impossible. I then judged that it was seven or eight miles distant. The day was remarkably clear and the land very distinct. By measurement we made the extent of coast of the Antarctic Continent, which was then in sight, seventy-five miles, and by approximate measurement 3000 feet high. It was entirely covered with snow. Longitude at noon 106° 18′ 42″ E., latitude 65° 59′ 40″ S., variation 57° 05′ westerly. On running in we had passed several icebergs, greatly discoloured with earth, and finding we could not approach the shore any nearer, I determined to land on the largest ice-island that seemed accessible, to make dip, intensity, and variation observations. On coming up with it, about one and a-half miles from where the barrier had stopped us, I hove the ship to, lowered the boats, and fortunately effected a landing. We found embedded in it in places, boulders, stones, gravel, sand, and mud or clay. The larger specimens were of red sandstone and basalt. No signs of stratification were to be seen in it, but it was in places formed of icy conglomerate (if I may use the expression), composed of large pieces of rocks, as it were frozen together, and the ice was extremely hard and flint-like. The largest boulder embedded in it was about 5 or 6 feet in diameter, but being situated under the shelf of the iceberg, we were not able to get at it. Many specimens were obtained, and it was amusing to see

the eagerness and desire of all hands to possess themselves of a piece of the Antarctic Continent. These pieces were in great demand during



VIEW OF THE ANTARCTIC CONTINENT.

the remainder of the cruise. In the centre of this iceberg was found a pond of most delicious water, over which was a scum of ice about 10 inches thick. We obtained from it about 500 gallons. We remained

upon this iceberg several hours, and the men amused themselves to their heart's content in sliding. The pond was three feet deep, extending over an area of an acre, and contained sufficient water for half-a-dozen ships. The temperature of the water was 31°. This island had been undoubtedly turned partly over, and had precisely the same appearance that the icy barrier would have exhibited if it had been turned bottom up and subsequently much worn by storms. There was no doubt that it had been detached from the land, which was about eight miles distant. The view of the land, ice, etc., taken from this ice-island, is exhibited in the opposite plate, and gives a correct representation of these desolate regions.

Around the iceberg we found many species of zoophytes, viz. salpee, a beautiful specimen of clio helicina, some large pelagie, and many large crustacea. I made several drawings of them. This day, notwithstanding our disappointment in being still repelled from treading on the new continent, was spent with much gratification, and gave us many new specimens from it.

Finding that we had reached the longitude of 105° E. before the time anticipated, and being desirous to pursue the discoveries further west, I left a signal flying on this berg, with a bottle containing instructions for the other vessels, directing them to proceed to the westward as far as they could in the time which should remain prior to the 1st of March. At 8 p.m. we joined the ship, and bore away again to the westward, intending to pursue the route pointed out to them.

On the 15th we passed many icebergs, much discoloured with earth, stones, etc., none of which appeared of recent formation. The weather this day became lowering, and the breeze fresh; we double-reefed the topsails and made everything snug; the wind was from the southward. At noon this day we were in longitude 104° E., latitude 64° 06′ S. The sea had been remarkably smooth the last few days, and no swell, and I began to entertain the idea that we might have a large body of ice to the northward of us, for the position where Cook found the barrier in 1773 was 200 miles further to the north. I determined, however, to pass on in our explorations, hoping they might enable me to join that of Enderby's Land. I deemed it a great object actually to prove the continuity with it if possible: and if disappointed in this, I should at any rate ascertain whether there had been any change in the ice in this quarter since the time of Cook, which had been done already near his Ne Plus Ultra.

We had a vast number of whales about us this day, as well as penguins, Cape pigeons, white and grey, and small and large petrels. Some seals also were seen.

I was now happy to find the health of my crew had become reestablished, and that only a few remained on the sick-list. This, I think, was effected by constant attention to their being warmly clothed.

The icebergs were covered with penguins; several officers landed on the icebergs to get a few as specimens. On their return some penguins followed them closely, particularly one, who at last leaped into the boat. It was supposed that its mate had been among those taken, and that it had followed on that account. If this were the fact, it would show a remarkable instinctive affection in this bird.

On the 16th the barrier of ice trended to the northward, and we were obliged to haul to the north-east, passing through a large number of ice-islands, many of which were stained with earth. In the afternoon a large sea-elephant was discovered on the ice; two boats were sent to effect his capture, and many balls were fired into him, but he showed the utmost indifference to their effect, doing no more than to raise his head at each shot. He contrived to escape by floundering over the ice until he reached the water, in which he was quite a different being.

At about 7 p.m. Dr. Fox was despatched in a boat to visit an ice-island that was very much discoloured with clay in patches. He reported that there was upon it a large pond of muddy water, not frozen, although the temperature on board was much below the freezing-point. We observed around the icebergs numerous right whales, puffing in all directions. A large quantity of small crustacea, including shrimps, were here seen around the icebergs. These are believed to be the cause that attracts whales to these parts; they also supply the numerous penguins with their food. For several days I observed a great difference in the wind, by day and by night. It had been fresh from the hour of seven in the morning until 8 p.m., when it generally becomes light or dies away altogether. To-day we found ourselves in longitude 99° E. and latitude 64° 21′ S. We to-day made observations throughout the twenty-four hours with Leslie's photometer. These results will be found embraced in the volume of Meteorology.

On the 17th, about 10 a.m., we discovered the barrier extending in a line ahead, and running north and south as far as the eye could reach. Appearances of land were also seen to the south-west, and its trending seemed to be to the northward. We were thus cut off from any further progress to the westward, and obliged to retrace our steps. This position of the ice disappointed me, although it concurred with what was reasonably to be expected. We were now in longitude 97° 37′ E. and latitude 64° 01′ S.; our variation was 56° 21′ westerly, being again on the decrease. To-day we had several snow-squalls, which, instead of being in flakes, was in small grains, as round as shot, and of various sizes, from that of mustard-seed to buck-shot. It was remarkably dry, pure white, and not at all like hail. We found the bay we had entered was fifty or sixty miles in depth, and having run in on its southern side, I determined to return along its northern shore, which we set about with much anxiety, as the weather began to change for the worse.

Our situation was by no means such as I should have chosen to encounter bad weather in, the bay being sprinkled with a great many large icebergs. Here we met with a large number of whales, whose curiosity seemed awakened by our presence. Their proximity, however, was anything but pleasant to us, and their blowings resembled that of a number of locomotives. Their close approach was a convincing proof that they had never been exposed to the pursuit of their skilful hunters. They were of the fin-back species, and of extraordinary size.

Between ten and eleven o'clock at night it was entirely clear overhead, and we were gratified with a splendid exhibition of the Aurora Australis. It exceeded anything of the kind I had heretofore witnessed; its activity was inconceivable, darting from the zenith to the horizon in all directions in the most brilliant coruscations; rays proceeding as if from a point in the zenith, flashed in brilliant pencillings of light, like sparks of electric fluid in vacuo, and reappear again to vanish; forming themselves into one body, like an umbrella, or fan, shut up; again emerging to flit across the sky with the rapidity of light, they showed all the prismatic colours at once or in quick succession. So remarkable were the phenomena that even our sailors were constantly exclaiming in admiration of its brilliancy. The best position in which to view it was by lying flat upon the deck, and looking up. The electrometer was tried, but no effect perceived. The star Canopus was in the zenith at the time, and though visible through the aurora, was much diminished in brightness. On this night also the moon was partially eclipsed.

Large icebergs had now become very numerous, and strengthened the belief that the land existing in this vicinity had taken a very decided trend to the northward. I accordingly followed up the northern barrier closely, and passed through the thickest of these bergs, well knowing from our experience that we should have little or no opportunity of seeing the land unless on the inner side of them. It appeared as though they had collected here from other places, and it is impossible to form an idea of the small space to which we were at times confined. Upwards of 100 ice-islands could be counted at a time without the aid of a glass, some of which were several miles long. We enjoyed this beautiful sight with the more pleasure, for we had become used to them, and knew from experience that it was possible to navigate through them without accident.

On the 18th we continued beating to the eastward, and found no end to the apparently interminable barrier. We had a smooth sea and better weather than I anticipated. At noon we had retraced our way about forty miles. To-day we again had snow, which fell in the form of regular six-pointed stars. The needles of which these stars were formed were quite distinct, and of regular crystals. The temperature at the time was 28°. The barometer stood at 28·76 in. about three-

tenths lower than we had had it for the last twelve days. The wind was easterly.

19th.—During this day the barrier trended more to the north-east, and we not unfrequently entered bays so deep as to find ourselves, on reaching the extremity, cut off by the barrier, and compelled to return to within a few miles of the place where we had entered. I thought at first that this might have been caused by the tide or current, but repeated trials showed none. Neither did I detect any motion in the floating ice except what was caused by the wind. Our longitude to-day was 101° E., latitude 63° 02′ S. Some anxiety seemed to exist among the officers and crew lest we should find ourselves embayed or cut off from the clear sea by a line of barrier. There appeared strong reason for this apprehension, as the smooth sea we had had for several days still continued, we had been sailing as if upon a river, and the water had not assumed its blue colour.

It was, therefore, with great pleasure that on the 20th a slight swell was perceived, and the barrier began to trend more to the northward, and afterwards again to the westward. In the morning we found ourselves still surrounded by great numbers of ice-islands. After obtaining a tolerably clear space, the day being rather favourable, we sounded with the deep-sea line 850 fathoms; Six's thermometer gave at the surface 31°, and at the depth of 850 fathoms 35°, an increase of four degrees. The current was again tried, but none was found. A white object was visible at 11 fathoms. The water had now assumed a bluish cast.

We endeavoured to-day to land on an iceberg, but there was too much sea. Shrimps were in great quantities about it, but swam too deep to be taken. The wind again hauled to the westward, which disappointed me, as I was in hopes of getting to the position where Cook saw the ice in 1773, being now nearly in the same latitude. It was less than 100 miles to the westward of us, and little doubt can exist that its situation has not changed materially in sixty-seven years.

The observations of the squadron during this season's Antarctic cruise, together with those of the preceding year, would seem to confirm the opinion that very little change takes place in the line of ice. It may be inferred that the line of perpetual congelation exists in a lower latitude in some parts of the southern hemisphere than in others. The icy barrier retreats several degrees to the south of the Antarctic Circle to the west of Cape Horn, while to the eastward it in places advances to the northward of that line, which is no doubt owing to the situation of the land. From the great quantities of ice to be found drifting in all parts of the ocean in high southern latitudes, I am induced to believe that the formation of the ice-islands is much more rapid than is generally supposed. The manner of their formation claimed much of my attention while among them, and I think it may be explained satisfactorily and without difficulty. In the first place, I conceive that ice requires a

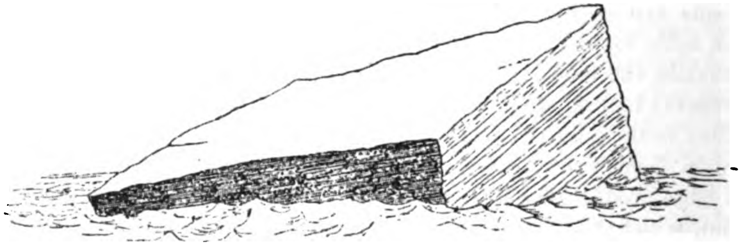
nucleus whereon the fogs, snow, and rain may congeal and accumulate; this the land affords. Accident then separates part of this mass of ice from the land, when it drifts off, and is broken into many pieces, and part of this may again join that which is in process of formation. The sketch in Chapter IX. has already given the reader some idea of its appearance in this state.

From the accumulation of snow, such a mass speedily assumes a flat or table-topped shape, and continues to increase. As these layers accumulate the field-ice begins to sink, each storm (there of frequent occurrence) tending to give it more weight. The part which is now attached to the land remains aground, whilst that which is more remote, being in deep water, is free to sink. The accumulated weight on its outer edge produces fissures or fractures at the point, where it takes the ground, which the frosts increase; thus separated, the surface again becomes horizontal, and continues to receive new layers from snow,

TABULAR ICEBERG.

rain, and even fogs, being still retained to the parent mass by the force of attraction. The fogs have no small influence in contributing to the accumulation; some idea may be formed of the increase from this cause, from the fact that during a few hours the ice accumulated to the thickness of a quarter-of-an-inch on our rigging and spars, though neither rain nor snow fell. It may therefore, I think, be safely asserted that these icebergs are at all times on the increase; for there are few days, according to our experience in this climate, in which some mode of precipitation does not prevail in these high latitudes, where, according to our observations, ice seldom melts. The temperature of even the summer months being rarely above the freezing point, masses of 1000 feet in thickness might require but few years to form. Icebergs were seen in all stages of formation, from 5 to 200 feet above the surface, and each exposed its stratification in horizontal layers from 6 inches to 4 feet in thickness. When the icebergs are fully formed they have a tabular and stratified appearance, and are perfectly wall-sided, varying from 180 to 210 feet in height. These were frequently found by us in their original situation, attached to the land, and having the horizontal stratification distinctly visible.

In some places we sailed for more than 50 miles together, along a straight and perpendicular wall, from 150 to 200 feet in height, with the land behind it. The icebergs found along the coast afloat were from a quarter of a mile to five miles in length; their separation from the land may be effected by severe frost rending them asunder, after which the violent and frequent storms may be considered a sufficient cause to



INCLINED ICEBERG.

overcome the attraction which holds them to the parent mass. In their next stage they exhibit the process of decay, being found 50 or 60 miles from the land, and for the most part with their surfaces inclined at a considerable angle to the horizon. This is caused by a change in the position of the centre of gravity, arising from the abrading action of the waves.

By our observations on the temperature of the sea, it is evident that these ice-islands can be little changed by the melting process before they reach the latitude of 60°. The temperature of the sea (as observed by the vessels going to and returning from the south) showed but little change above this latitude, and no doubt it was at its maximum, as it was then the height of the summer season.

During their drift to the northward, reaching lower latitudes, and as

ICEBERG.

their distance from the land increases, they are found in all stages of decay; some forming obelisks; others towers and Gothic arches; and all more or less perforated; some exhibit lofty columns, with a natural bridge resting on them, of a lightness and beauty inconceivable in any other material. The annexed wood-cut and the tail-pieces of the chapters are sketches of some of them.

While in this state they rarely exhibit any signs of stratification, and some appear to be formed of a soft and porous ice; others are quite blue; others, again, show a green tint, and are of hard flinty ice. Large ice-islands are seen that retain their tabular tops nearly entire until they reach a low latitude, when their dissolution rapidly ensues; while some have lost all resemblance to their original formation, and had evidently been overturned. The process of actually rending asunder was not witnessed by any of the vessels, although in the *Flying-Fish*, when during fogs they were in close proximity to large ice-islands, they inferred from the loud crashing, and the sudden splashing of the sea on her, that such occurrences had taken place. As the bergs gradually become worn by the abrasion of the sea, they in many cases form large overhanging shelves, about 2 or 3 feet above the water, extending out 10 or 12 feet; the under part of this projecting mass exhibits the appearance of a collection of icicles hanging from it. The temperature of the water, when among the icebergs, was found below or about the freezing point.

I have before spoken of the boulders embedded in the icebergs. All those that I had an opportunity of observing, apparently formed a part of the nucleus, and were surrounded by extremely compact ice, so that they appear to be connected with that portion of the ice that would be the last to dissolve, and these boulders would therefore, in all probability be carried to the farthest extent of their range before they were let loose or deposited.

The ice-islands, on being detached from their original place of formation by some violent storm, are conveyed to the westward by the south-east winds which are prevalent here, and are found, the first season after their separation, about seventy miles north of the barrier. This was inferred from the observations of both the *Vincennes* and *Porpoise*, the greatest number having been found about that distance from the barrier. That these were recently detached is proven by their stratified appearance; while those at a greater distance had lost their primitive form, were much worn, and showed many more signs of decay. Near the extreme point of the barrier visited, in longitude 97° E., latitude 62° 30′ S., and where it begins to trend to the westward, vast collections of these islands were encountered. From this point they must pass to the northward during the next season, partly influenced by the current, and partly scattered by the prevailing winds, until they reach the sixtieth degree of latitude, when they encounter the easterly and north-easterly streams that are known to prevail, which carry them rapidly to the north.

Our data for their actual drift, though not altogether positive, are probably the best that can be had, and will go far towards ascertaining the velocity of their progress to lower latitudes; our observations also furnish some estimate of the time in which they are formed. On our

way south we did not fall in with ice-islands until we reached latitude 61° S. The *Peacock* was the first to return, and nearly upon the track by which we had gone south; the last seen by her was in 55° S. The *Vincennes*, on her return fifty days later, saw them in 51° S. The *Porpoise*, about the same time, in 53° S. The observation in the *Vincennes* gives a distance of ten degrees of latitude, or 600 miles to be passed over in fifty days, which would give about half a mile an hour; or, taking the *Peacock's* observations, a more rapid rate would be given, nearly three-fourths of a mile. Many icebergs were met in the latitude of 42° S., by outward-bound ships to Sydney, in the month of November; these, I learned, were much worn, and showed lofty pinnacles, exhibiting no appearance of having ever been of a tabular form. These no doubt are such as were detached during a former season, and being disengaged from the barrier, would be naturally, early the next season, drifted by the easterly current as well as the westerly wind, and would pursue the direction it gives them. They would, therefore, be driven to the north-east as far as the south-west winds prevail, and when these veer to the westward would receive an easterly direction; it is where these winds prevail that they are most frequently found by the outward-bound vessels—between the latitudes of 40° and 50° S.

Respecting the period of time required for the formation of these ice-islands, much light cannot be expected to be thrown on the subject; but the few facts derived from observations lead to some conclusions. Many of them were measured, and their altitude found to be from 50 to 250 feet; eighty distinct stratifications were counted in some of the highest, and in the smallest thirty, which appeared to average a little more than two feet in thickness. Supposing the average fall of snow in these high latitudes to be an inch a day, or 30 feet a year, the largest icebergs would take more than thirty years to form. They were seen by us in all the stages of their growth, and all bore unequivocal marks of the same origin. The distance from the land at which they were forming, fully satisfied me that their fresh water could only be derived from the snows, etc.

The movement of the ice along the coast is entirely to the westward, and all the large range of ice-islands and bergs were found in that direction, while the eastern portion was comparatively free from it. A difference was found in the position of the floe-ice by the different vessels, caused rather by the wind than by the tide. When the *Vincennes* and *Porpoise* passed the opening by which the *Peacock* entered, it was found closed, although only twenty-four hours had elapsed. It has been seen that the ice had much movement during the time the *Peacock* was beset by it, and the bay was all but closed when she effected her escape. Another instance occurred where the *Porpoise*, in about the longitude of 130° E., found the impracticable barrier a few miles further south than the *Vincennes* did six or seven days after; but

this fact is not to be received as warranting any general conclusion, on account of the occurrence of south-east gales during the intermediate time. The trials for currents have, for the most part, shown none to exist. The *Porpoise*, it is true, experienced some, but these were generally after a gale. If currents do exist, their tendency is westward, which I think the drift of the ice would clearly prove. The difference between the astronomic positions and those given by dead-reckoning was no avail here as a test,* for the courses of the vessels among the ice were so tortuous that the latter could not be depended upon.

The winds which prevail from the south-west to the south-east occasionally bring clear weather, interrupted by flurries of snow; the north wind is light, and brings thick fogs, attended by a rise of temperature. Extremes of weather are experienced in rapid succession, and it is truly a fickle climate.

The evidence that an extensive continent lies within the icy barrier must have appeared in the account of my proceedings, but will be, I think, more forcibly exhibited by a comparison with the aspect of other lands in the same southern parallel. Palmer's Land, for instance, which is in like manner invested with ice, is so at certain seasons of the year only, while at others it is quite clear, because strong currents prevail there which sweep the ice off to the north-east. Along the Antarctic Continent for the whole distance explored, which is upwards of 1500 miles, no open strait is found. The coast, where the ice permitted approach, was found enveloped with a perpendicular barrier, in some cases unbroken for fifty miles. If there were only a chain of islands, the outline of the ice would undoubtedly be of another form; and it is scarcely to be conceived that so long a chain could extend so nearly in the same parallel of latitude. The land has none of the abruptness of termination that the islands of high southern latitudes exhibit; and I am satisfied that it exists in one uninterrupted line of coast, from Ringgold's Knoll, in the east, to Enderby's Land, in the west; that the coast (at longitude 95° E.) trends to the north, and this will account for the icy barrier existing, with little alteration, where it was seen by Cook in 1773. The vast number of ice-islands conclusively points out that there is some extensive nucleus which retains them in their position; for I can see no reason why the ice should not be disengaged from islands, if they were such, as happens in all other cases in like latitudes. The formation of the coast is different from what would probably be found near islands, soundings being obtained in comparatively shoal water; and the colour of the water also indicates that it is not like other southern lands, abrupt and precipitous. This cause is sufficient to retain the huge masses of ice, by their being attached by their lower surfaces instead of their sides only.

* The fact of there being no northerly current along this extended line of coast is a strong proof in my mind of its being a continent, instead of a range of islands.

Much inquiry and a strong desire has been evinced by geologists to ascertain the extent to which these ice-islands travel, the boulders and masses of earth they transport, and the direction they take.

From my own observations and the information I have collected, there appears a great difference in the movements of these vast masses; in some years great numbers of them have floated north from the Antarctic Circle, and even at times obstructed the navigation about the Capes. The year 1832 was remarkable in this respect; many vessels bound round Cape Horn, from the Pacific, were obliged to put back to Chili, in consequence of the dangers arising from ice; while during the preceding and following years little or none was seen; this would lead to the belief that great changes must take place in the higher latitudes, or the prevalence of some cause to detach the ice-islands from the barrier in such great quantities as to cover almost the entire section of the ocean south of the latitude 50° S. Taking the early part of the (southern) spring as the time of separation, we are enabled to make some estimate of the velocity with which they move: many masters of vessels have met them, some 600 or 700 miles from the barrier, from sixty to eighty days after this period, which will give a near approximation to our results heretofore stated.

The season of 1839 and 1840 was considered as an open one, from the large masses of ice that were met with in a low latitude by vessels that arrived from Europe at Sydney; many of them were seen as far north as latitude 42° S.

The causes that prevail to detach and carry them north are difficult to assign. I have referred to the most probable ones that would detach them from the parent mass in their formation. Our frequent trials of currents, as has been stated, did not give us the assurance that any existed; but there is little doubt in my mind that they do prevail. I should not, however, look to a surface-current as being the motive power that carries these immense masses at the rate they move; comparatively speaking, their great bulk is below the influence of any surface-current, and the rapid drift of these masses by winds is still more improbable. Therefore I conceive we must look to an under-current as their great propeller. In one trial of the deep-sea thermometer, we found the temperature beneath four degrees warmer than the surface. Off Cape Horn the under temperature was found as cold as among the ice itself; repeated experiments have shown the same to occur in the Arctic regions. From this I would draw the conclusion that changes are going on, and it appears to me to be very reasonable to suppose that at periods currents to and from the poles should at times exist; it is true we most generally find the latter to prevail, as far as our knowledge of facts extends, but we have not sufficient information yet to decide that there is not a reflow towards the pole; the very circumstance of the current setting from the higher latitudes would seem a good argument that there must be some

counter-current to maintain the level of the waters. These masses, then, are most probably carried away in the seasons when the polar streams are the strongest, and are borne along by them at the velocity with which they move; that these do not occur annually may be inferred from the absence of ice-islands in the lower latitudes; and that it is not from the scarcity of them those who shared the dangers of the Antarctic cruise will, I have little doubt, be ready to testify; for, although great numbers of them studded the ocean that year, yet the narrative shows that vast numbers of them were left.

The specific gravity of the ice varies very much, as might naturally be expected; for while some of it is porous and of a snowy texture, other islands are in great part composed of a compact blue, flinty ice. This difference is occasioned by the latter becoming saturated with water, which afterwards freezes.

On the ice there was usually a covering of about two feet of snow, which in places had upon it a crust of ice not strong enough to bear the weight of a man. Those ice-islands, which after having been once seen, were again passed through immediately after a gale, were observed to be changed in appearance; but though for forty-eight hours a severe storm had been experienced, they had not undergone so great a transformation as not to be recognised. They also appeared to have shifted their position with regard to one another, their former bias and trendings being broken up.

During our stay on the icy coast I saw nothing of what is termed pack-ice—that is, pieces forced one upon the other by the action of the sea or currents.

On the 21st the weather became unsettled, with light westerly winds, and we made but little progress to the westward. The barrier, at 6 p.m., was seen trending to the westward. In consequence of indications that threatened bad weather, I deemed it useless risk to remain in the proximity of so many ice-islands, and a strong breeze, with squally weather, having already set in, I took advantage of it, feeling satisfied that our farther continuance in this icy region would not only be attended with peril to the ship, but would cause a waste of the time which was demanded by my other duties; and having nearly 3000 miles to sail to our next port (Bay of Islands), I made up my mind to turn the head of the vessel northward.

I therefore had the officers and crew called aft, thanked them all for their exertions and good conduct during the trying scenes they had gone through, congratulated them on the success that had attended us, and informed them that I had determined to bear up and return north.

Having only twenty-five days' full allowance of water, I ordered its issue to be reduced to half allowance.

I have seldom seen so many happy faces, or such rejoicings, as the announcement of my intention to return produced. But although the

crew were delighted at the termination of this dangerous cruise, not a word of impatience or discontent had been heard during its continuance. Neither had there been occasion for punishment; and I could not but be thankful to have been enabled to conduct the ship through so difficult and dangerous a navigation without a single accident, with a crew in as good, if not in better condition than when we first reached the icy barrier. For myself, I indeed felt worse for the fatigues and anxieties I had undergone; but I was able to attend to all my duties, and considered myself amply repaid for my impaired health by the important discoveries we had made, and the success that had attended our exertions.

I shall now leave the *Vincennes* to pursue her route northward, and return to the *Porpoise*, the result of whose proceedings will be detailed in the following chapter.

CHAPTER XI.

Antarctic Cruise—*continued.*

1840.

Proceedings of the *Porpoise* from the 22nd to the 30th of January—French squadron seen—Its commander refuses to speak the *Porpoise*—Proceedings up to the 3rd of February—Gale—Further proceedings to the 12th of February—Specimens of rock obtained—Western limit of her cruise—Return to the eastward—*Porpoise* stands to the northward—Auckland Islands—*Porpoise* arrives at the Bay of Islands—Cruise of the *Flying Fish*—Landing at Macquarie's Island—Proceedings of the *Flying Fish* up to the 4th of February—State of her crew—Their letter to Lieutenant Pinkney—He resolves to return—Arrival of the *Flying Fish* at the Bay of Islands—Events during the return of the *Vincennes*—She fails to reach Van Diemen's Land—Arrival of the *Vincennes* at Sydney—*Peacock* found there—Return of the *Peacock* from the icy barrier—She makes Macquarie's Island—She arrives at Sydney—State of the *Peacock*—Hospitalities received at Sydney.

On the 22nd January the *Porpoise* lost sight of the *Peacock*, and continued beating to the south-west. The weather was extremely cold; some shrimps were caught; sea-water froze on being a few minutes in the bucket on deck. The water at 3 p.m. was much discoloured; got a cast of the lead with 200 fathoms—no bottom; found the current south by east, three-fourths of a mile per hour. At 4.30 passed large icebergs, one of which had several dark horizontal veins, apparently of earth, through it; large quantities of floe and drift-ice to the southward; the sea very smooth. A report of high land was made this morning; indeed, everything indicated the proximity of land. The number of seals, whales, penguins, shrimps, etc., had very much increased. The pure white pigeons were also seen in numbers.

23rd.—Countless icebergs in sight; the sea quite smooth, not the slightest motion perceptible. At meridian they were in latitude 66° 44′ S., longitude 151° 24′ E., and close to the barrier, which appeared quite impenetrable, as far as the eye could reach from aloft, to the north-north-west and north-north-east, with numberless immense ice-islands entangled and enclosed in it in all directions. The position they occupied seemed an inlet of elliptical shape, with an opening to the north. It was needless to count the many scattering islands of ice distinct from the vast chain; intermingled with field-ice, they studded the gulf like so many islands, of various shapes and dimensions. At 2.25 a sail was discovered on the lee bow; kept off to communicate, supposing it to be the *Vincennes* or *Peacock*. At 2.30 the *Peacock* was made out on the southern board, showing no disposition to communicate; showed our colours, and hauled to the westward.

24th.—The day was remarkably fine, such as is seldom experienced in this region. The water appeared much discoloured and of a dirty olive-green colour. At meridian they again made the field-ice, and tacked to the northward, passing through large quantities of ice-islands; weather looking bad, with occasional light snow-storms.

25th.—Part of this day was clear and pleasant, though snow fell at intervals; the field-ice was in sight several times, and many ice-islands of great size and beauty. Penguins were swimming round, and also several shoals of black-fish; a black albatross was shot; towards night the weather became very thick; they were in longitude 150° E., latitude 65° 56′ S.

26th.—Fresh winds blowing from the eastward; during the first few hours a thick snow-storm; at 4 a.m. it cleared; at 6 o'clock made a sail; the strange sail fired a gun and made signal, when we bore down and spoke her; she proved to be the *Vincennes;* compared chronometers and received rate; bore off to tho westward under all sail; found the drift and the floe-ice very thick, and were with great difficulty enabled to navigate through it; wind fresh, with a long swell from the south-west. At 5.30, the ice increasing in quantity, found it was necessary to haul off. Lost sight of the *Vincennes.* Weather very threatening. The course during the day proved a very tortuous one. Many penguins resting on the ice; their gait is an awkward kind of strut.

Received orders to-day by signal to meet the *Vincennes* along the icy barrier between the 20th and 28th of next month.

27th.—This day proved clear and cold; wind from the south-west; ice forming rapidly on the vessel; at meridian lost sight of the *Vincennes*; very many ice-islands in sight; latitude 65° 41′ S., longitude 142° 31′ E. On this day Lieutenant-Commandant Ringgold determined with the fair wind to pass to the extreme limit of his orders, longitude 105° E., being of opinion he would thereby save time, and be enabled more effectually to examine the barrier with what he thought would be

found the prevailing wind, viz. that from the westward; in this, however, he was mistaken.

The 28th set in with a light breeze from east-north-east; made all sail. At 5 a.m. wind increasing rapidly, snow falling fast, and weather becoming thick. At 6 o'clock made the floe and drift-ice; shortened sail and hauled off to the north-west, it becoming so thick as to render any advance unsafe. Until meridian very strong winds from the eastward; the brig under close-reefed topsails. At 2 p.m. found it difficult and hazardous to proceed, passing within a short distance of ice-islands, and just seeing them dimly through obscurity. At three the brig was hove-to, and Lieutenant-Commandant Ringgold says, in reference to their situation:—

"I felt great anxiety to proceed, but the course was so perilous, the extent and trend of the barrier so uncertain, I could not reconcile it with prudence to advance. The frequent falling in with fields of drift-ice, the numerous and often closely grouped chains of icebergs, were sufficient to point out discretion. The long-extended barrier was encountered in latitude 65° 08′ S.; at 12 to-day our position was 65° 16′ S. It is easy to perceive the possibility of a trend northerly again, which would have placed us in a large and dangerous gulf, with a heavy gale blowing directly on, without a hope of escape.

"At 8 p.m. blowing very heavy; the snow falling rendered vision beyond a few yards impossible. I have seldom experienced a heavier blow, and towards the conclusion the squalls were severe and frequent."

The barometer at 3 a.m. stood at 28·200 in., the lowest point it reached during the gale. The temperature of the air was 26°.

The severe gale continued during the 29th, with a heavy sea, and snow falling thickly. At 8 a.m. the gale abated, and the clouds broke away; through the day the sun occasionally out; the weather appeared unsettled; the sun set red and fiery; the latitude was observed 64° 46′ S., longitude 137° 16′ E.

On the 30th they stood again to the south-west; at 2 a.m. they made the barrier of field-ice, extending from south-east to west, when it became necessary to haul more to the north-west; the weather becoming thick with a heavy fall of snow, at four o'clock, the wind increasing, compelled them to shorten sail; at 7.30 the ice in fields was discovered close aboard, heading west; at this time hauled immediately on a wind to the north-east, and soon passed out of sight of the ice and out of danger; during the day blowing a gale of wind, and very heavy sea running, passing occasional ice-islands; at meridian, being clear of the barrier, the brig was hove-to under storm-sails, to await the clearing of the weather. In the afternoon the weather showed signs of clearing; the sun coming out, again made sail to approach the barrier; no ice in sight; great numbers of black petrels about.

At 4 p.m. discovered a ship ahead, and shortly after another was

made, both standing to the northward; the brig hauled up to the north-west, intending to cut them off and speak them, supposing them to be the *Vincennes* and the *Peacock*; shortly afterwards they were seen to be strangers, being smaller ships than our own; at 4.30 the *Porpoise* hoisted her colours. Knowing that an English squadron under Captain Ross was expected in these seas, Lieutenant-Commandant Ringgold took them for his ships, and was, as he says, "preparing to cheer the discoverer of the North Magnetic Pole."

"At 4.50, being within a mile and a half, the strangers showed French colours; the leeward and sternmost displayed a broad pennant; concluded now that they must be the French discovery ships under Captain D'Urville,* on a similar service with ourselves: desirous of speaking and exchanging the usual and customary compliments incidental to naval life, I closed with the strangers, desiring to pass within hail under the flag-ship's stern. While gaining fast, and being within musket-shot, my intentions too evident to excite a doubt, so far from any reciprocity being evinced, I saw with surprise sail making by boarding the main tack on board the flag-ship. Without a moment's delay, I hauled down my colours and bore-up on my course before the wind."

It is with regret that I mention the above transaction, and it cannot but excite the surprise of all that such a cold repulse should have come from a French commander, when the officers of that nation are usually so distinguished for their politeness and attention. It was with no small excitement I heard the report of it—that the vessels of two friendly powers, alike engaged upon an arduous and hazardous service in so remote a region, surrounded with every danger navigators could be liable to, should meet and pass without even the exchange of common civilities, and exhibit none of the kind feelings that the situation would naturally awaken:—how could the French commander know that the brig was not in distress or in want of assistance? By refusing to allow any communication with him, he not only committed a wanton violation of all proper feeling, but a breach of the courtesy due from one nation to another. It is difficult to imagine what could have prompted him to such a course.

At 6 p.m. the weather again was thick, with the wind south-easterly; field-ice again in sight; it commenced snowing, and the French ships were lost sight of. At 8 p.m. they passed in sight of large fields of ice and ice-islands; at 10.30, the snow falling so dense and the weather so thick that it was impossible to see the brig's length in any direction, she was hove-to, to await a change of weather.

The beginning of the 31st the gale continued; at 7 a.m., moderating, they again made sail to the westward; in half an hour discovered a high barrier of ice to the northward, with ice-islands to the southward; at 10 a.m. they found themselves in a great inlet formed by vast fields

* See Dumont D'Urville's account on page 457.

of ice, which they had entered twelve hours previously; the only opening appearing to the eastward, they were compelled to retrace their steps, which they effected at 8 p.m., passing some ice-islands which they recognised as having been seen the evening before. They now found themselves out of this dangerous position, and passing the point, kept away to the westward. Lieutenant-Commandant Ringgold judged it prudent to heave-to during the night, on account of the darkness.

Feb. 1.—The immense perpendicular barrier encountered yesterday was now in sight, trending as far as the eye could reach to the westward; it was of tabular form, from 150 to 180 feet in height, of solid compact ice, resembling a long line of coast; wind moderate from the south-east. A brilliant blink extending along and elevated above the barrier. At 4 p.m. they arrived at the end of this barrier, and found it trending off to the southward, seeming as if numbers of icebergs had been broken from the barrier by some mighty force, exceeding in numbers anything that had yet been seen, extending as far south as could be distinguished, interspersed with much drift and floe-ice. On the southern horizon sixty-four ice-islands were counted, exclusive of many near them and those that were not distinguishable from the barrier.

The current was tried here, and found setting south-east nearly a mile an hour. Pigeons around in numbers, also whales and large flocks of penguins.

The nights now evidently lengthened, thus adding to the cares and anxieties attendant on this navigation. It was fortunate that the prevailing winds were from the south-east and south-west, or coming off the ice. If they had blown from the northward they would have been attended with danger, and might have proved fatal to the vessel.

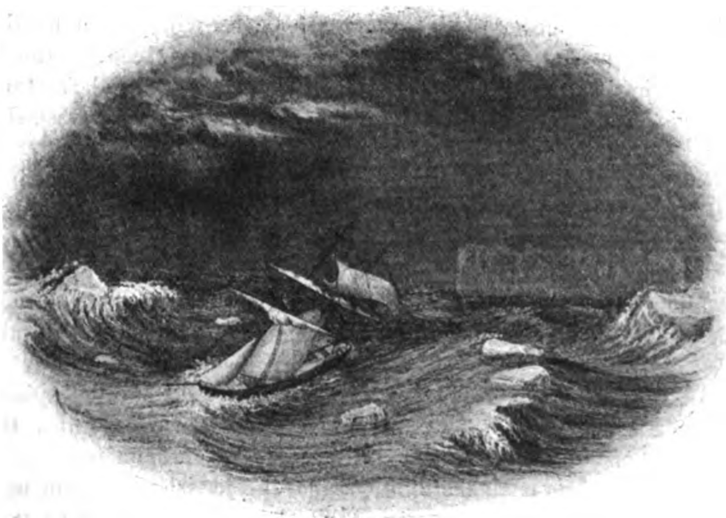
2nd.—At meridian, in longitude 130° 36′ E., and latitude 65° 24′ S. They were prevented from proceeding farther to the southward by the impenetrable icy barrier. At this time they had one hundred large ice-islands in sight, without counting any of the smaller bergs, which were innumerable; saw great numbers of penguins and some seals (*Phoca proboscidæ*). The current was tried here, and found setting as yesterday, and at the same rate.

At 8 p.m. were obliged to retrace their steps to the northward, the weather becoming thick, with light snow. At eleven, constant and thick snowstorm, and unable to see any distance; the gale continuing, lay-to under a close-reefed main-topsail. The vignette, from a sketch by Mr. Totten, will give some idea of her situation.

3rd.—A gale from south-east, heavy sea rising; occasionally passing ice-islands and field-ice. The gale continued throughout the day, but moderated towards midnight; the sea was heavy, the weather thick, and the brig completely covered with ice and snow. The barometer fell to 28·240 in. Temperature of the air 32°.

4th.—Although the wind was moderate, yet it was so thick and foggy as to preclude bearing up. Towards meridian it cleared sufficiently for them to bear up and continue their examinations. To-day the current was found west-north-west, three-quarters of a mile per hour.

On the 5th they had a beautiful day—no climate or region, Lieutenant-Commandant Ringgold remarks, could have produced a finer—this gave them an opportunity of thoroughly drying everything and ventilating the vessel, which was much required; standing to the northward, in order to make a long board to the westward; the longitude 127° 08′ E., latitude 63° 22′ S.; few ice-islands in sight, and those appeared much



THE 'PORPOISE' IN A GALE.

worn, showing marks of rapid decay, with isolated pieces—some standing erect, while others were inclined, resembling fragments of columns and broken arches. This night there was a brilliant display of the Aurora Australis; at eleven o'clock there was perceived in the northern horizon a luminous arched cloud at 15° of altitude, extending from north-west to north-east; the stars were partially obscured in the direction of the clouds; the pale flashes or coruscations vanishing very suddenly, were succeeded by spiral columns or streamers, converging with great velocity towards the zenith; brilliant flashes would again issue forth from the remote parts of the cloud, succeeded in quick succession by perpendicular rays emanating from the cloud, having the shape of a rounded column or basaltic-shaped cylinder, which in contrast with the dark cloud showed in broad relief. As the cloud seemed

to rise, the scene became a most interesting one, from the varied and oft-changing coruscations: finally, the arc assumed a contracted and elliptical form, vivid streamers bursting forth as if from a corona, converging all towards the zenith, until they were lost in the coming day. The magnetic needle did not show any disturbance. The barometer stood stationary during its continuance. The sympiesometer indicated a slight fall. At the time there was no wind; the stars were brilliant, and all visible.

6th.—During this day they had light winds; pursued their course to the westward; wind from the southward. In the afternoon they had light flurries of snow, and at times hail; the sea perfectly smooth, and few icebergs in sight. Longitude 125° 32′ E., latitude 63° 34′ S.

During the 7th the winds variable. At eight tacked to the southward in order to close in with the barrier; the wind again hauling, tacked; the number of icebergs increasing; all those seen for the few days past have appeared variously shaped, much worn and fractured, some evidently overturned, and immense arches or caves washed in them; they were totally distinct from those seen to-day.

8th.—A brisk breeze from the southward, which carried them on rapidly to the westward. At meridian discovered compact fields of ice, with many stupendous ice-islands enclosed within it; the ice appeared more broken than any hitherto seen, with many fragments of icebergs resembling spires and broken columns. Altered their course to clear the barrier, and by two o'clock they had extricated themselves. Penguins, whales, brown pigeons, and the black albatross were seen near the barrier. In the afternoon the snow fell in beautiful shining spiculæ, resembling stars, usually of six, but sometimes of twelve points; they varied from one-eighth to one-sixteenth of an inch in diameter.

The barrier was occasionally seen, and the ice-islands began again to assume a tabular form; towards the close of the day very many whales, penguins, etc., seen. Longitude 116° E., latitude 64° 01′ S.

On the 9th, fresh breezes from the south-east. At 10 a.m. made the barrier again, the weather being favourable. At 4 p.m., standing along the barrier, through drift-ice, with countless icebergs in sight, good observations were obtained, placing them in longitude 112° 41′ E., and latitude 64° 55′ S. At 10 p.m. some few appearances of the Aurora Australis in the northern sky, light coruscations streaming upwards, but quite faint, and only for a very short period; many stars and several constellations were traced without difficulty. The sea was smooth; lowered a boat to try the current, but found none. The dip was 83° 30′.

On the morning of the 10th the weather cleared off, and gave them an opportunity of ventilating the vessel; closed in with the field-ice for the purpose of obtaining a supply of water, and the boats were despatched to take in ice. The longitude was found to be 110° 34′ E., latitude 65° 12′ S. The field-ice here was found to be interspersed with many

large ice-islands and bergs. At 5 o'clock the boats returned with ice. The current was found to be setting north-north-east, 5 fathoms an hour; the weather continued clear and healthful; made the field-ice ahead and on the lee bow; shortly after, cleared it. The twilight in the southern horizon presented a beautiful appearance, a bright salmon colour radiating from the sun throwing its tints over the whole sky, tinging the few cirro-stratus clouds that were in the northern quarter, and giving a soft colour to the immense ice-islands that were slumbering along the barrier, and aiding to lend to the scene its peculiar character of silence, solitude and desolation.

The weather was clear and pleasant on the 11th, with a light wind from the south-east; many penguins and whales were seen. The icebergs were numerous, and some of great beauty, with almost regularly turned arches, and of the most beautiful aqua-marine tints. Longitude was 106° 10′ E., latitude 65° 28′ S.

During the morning of the 12th running along high broken fields of ice, with a light breeze from the southward; weather overcast. Discovered a large piece of ice of a dark-brown colour floating by, resembling a piece of dead coral; lay-to, and sent a boat to bring it alongside; obtained from it several pieces of granite and red clay, which were frozen in. The ice was extremely hard and compact, composed of alternate layers of ice and snow; the strata of snow were filled with sand. The icebergs near at the time presented signs of having been detached from land, being discoloured by sand and mud. A number of white procellaria were obtained. The ice-islands again appeared in great numbers. At 3 p.m. hauled up, steering westerly into a very deep inlet or gulf, formed by extensive fields of ice, believing from the indications of the morning that land could not be far off. In approaching the head of this inlet, several icebergs had the appearance of being in contact with the land, having assumed a dark colour from the clay and sand blown upon them; the whole group around seemed as if in the vicinage of land. Sounded with 200 fathoms—no bottom; also tried the current, but found none. Towards night, it becoming thick with snow, they continued under snug sail, intending to examine more closely the barrier and inlets in the morning.

13*th*.—At 3 a.m. they again made sail to the westward, with wind from the east; at six o'clock they had snow-squalls, rendering it unsafe to proceed and impossible to make any discovery. A few hours afterwards the weather cleared a little; made sail again to the north-west. At meridian overcast, with a stiff south-east breeze; at 1.30 approached to within pistol-shot of the barrier, observing much of the dark, dirty ice interspersed with the field-ice; kept along it very closely, tracing the barrier northerly; observed a large black object on the ice; shortened sail, and despatched a boat: it proved to be a large mass of black, red, and mixed-coloured earth, resting upon a base of snow and ice,

situated some fifty yards back from the margin of the field-ice, and was found to be red earth mixed with granite and sandstone. Penguins were also procured alive. At 3 p.m. they again followed the trend of the ice in a north-westerly direction; a vast field, of uninterrupted extent, seemed moving along to the westward, the large icebergs containing dark and discoloured masses, with frequent strata of the same description. They were still at a loss to account for these frequent signs of land: discoloured pieces of ice seemed mingled with the general mass; they were often seen along its margin, and appeared as though the icebergs had been turned over, presenting collections as if from the bottom. Great numbers of sperm whales were seen this day. At 8 p.m. they passed out northwardly, with a light breeze and smooth sea, through an extensive chain of icebergs, which seemed grouped off the western point of the barrier: upwards of 100 of them were counted, several of which were very much discoloured. The sunset was brilliant, bright crimson tints illuminating the icebergs and producing a beautiful effect.

On the 14th Lieutenant-Commandant Ringgold, having passed a few degrees beyond his instructions, that is, having reached longitude 100° E., and latitude 64° 15′ S., now commenced his return, in order to examine those places in the barrier which he had been prevented from doing on his way west.

15th.—Continued their course to the eastward. Lieutenant-Commandant Ringgold frequently refers to the happy and cheerful condition of his crew, and their freedom from all disease.

On the 16th and 17th they were employed in getting to the eastward, passing many worn and shattered bergs. On the evening of the latter day they had another exhibition of the Aurora Australis, extending from north-north-west to east; it was of a light straw-colour, but very indistinct; the luminous bank was at an elevation of 30°. The light in the north-west was most distinct, radiating from a nucleus above the horizon towards the zenith, where it formed a beautiful halo. It was not of long duration. Many ice-islands and bergs in sight, upwards of 200; nearly all of a tabular form—the sides of many of them beautifully excavated by the waves, presenting innumerable Gothic arches, extending often to a considerable distance into the body of the ice.

Their position on the 18th was in longitude 114° 17′ E., latitude 62° 37′ S. Flocks of black birds were very numerous, but not near enough to be taken.

On the 19th and 20th, proceeding to the eastward. On the 20th they had but few ice-islands in sight, although they were 70 miles further south than on the 18th, when the largest number ever seen by them at one time was visible. Having reached the longitude of 120° E., they again steered south to make the barrier. The current was tried, but none found.

The 21st proved stormy, with strong breezes from the south-east, and

much snow and rain, which covered the brig with ice. Field-ice was seen ahead, when they again stood to the eastward, longitude being 121° 30′ E., latitude 65° 15′ S. On this night they experienced a heavy gale, during which the barometer fell to 27·50 in., where it remained during part of the 22nd. The squalls were very severe, accompanied with snow, sleet, hail, and heavy seas: they had now reached longitude 122° E., and latitude 64° 09′ S.

February 22nd, being Washington's birthday, the colours were hoisted, and the crew received an extra allowance. Lieutenant-Commandant Ringgold took this occasion to express to them his satisfaction for the manner in which they had performed their duties during the present cruise, and that their conduct would be duly represented to the commander of the expedition and the government.

On the 23rd the weather was again thick, with snow and mist.

On the 24th they had reached longitude 126° E., and latitude 64° 29′ S. On this day they again sighted the barrier; when, having completed what he deemed a full execution of his instructions, Lieutenant-Commandant Ringgold determined to put the brig's head north,—which was accordingly done.

Strong winds and gales continued for the next three days. On the 27th they again found themselves in east variation, in longitude 138° E., latitude 60° 08′ S. The white albatross had now again become common.

On the 29th they had a beautiful display of the Aurora Australis; the whole southern hemisphere was covered with arches of a beautiful straw-colour, from which streamers radiated, both upwards and downwards, of almost a lustrous white; numbers of concentric arches would occasionally show themselves, of a width of a few feet, uniting to form a complete canopy for a moment, and then vanish. The arches extended from east-south-east to west-north-west; the display continued for over two hours; the stars were seen above them. Previous to, and during its continuance, the thermometer indicated a change of four degrees, and the wind shifted to the southward.

On the 1st of March, in latitude 55° S. and longitude 140° E., they passed the last ice-island.

On the 2nd, great numbers of pyrosoma of large size were passed.

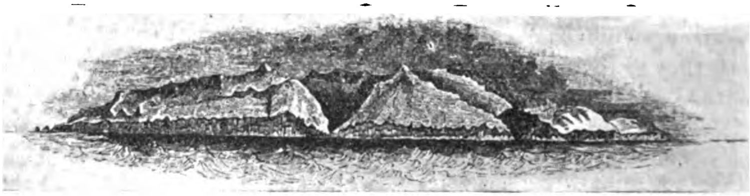
On the 4th, some faint appearances of the Aurora Australis were seen.

On the 5th the Lord Auckland Isles were descried. Mr. Totten, who was officer of the deck, was accidentally knocked overboard by the trysail-boom, but was fortunately rescued without injury. Immense numbers of albatrosses were about. The aurora was again seen in the southern hemisphere.

On the 7th they anchored in the harbour of Sarah's Bosom, in twelve fathoms water. During their brief stay here all were actively employed wooding and watering, for which this harbour affords a fine

opportunity. Assistant-Surgeon Holmes made several excursions on the largest island, of which he gives the following account.

"I found it very thickly covered with trees in its less elevated parts. As few of them were of any size, I found no small difficulty in penetrating and making my way through them: in many places it was absolutely impossible. It was only after a long and fatiguing walk that I succeeded in reaching the summit of that part of the island near which the brig was anchored, where I found the trees less numerous. A thick growth of underwood and dwarf bushes, intermixed with ferns, concealed the surface, rendering it difficult to walk. Even on the places apparently most level the ground was very unequal, and a single step would sometimes send me nearly up to the neck into a hollow filled with large fern fronds. On the highest parts the small level spots were covered only with moss and a description of tall grass, and in places also a kind of grain grew abundantly. The ground was dry everywhere, all the water being found in the streams, which were numerous and pure. Near the summit the ground was perforated in all direc-



AUCKLAND ISLES.

tions, probably by birds, who rear their young in these holes. Many of the birds, principally procellaria, were sitting on the ground; they made no effort to escape, but suffered themselves to be taken without any attempt at resistance.

"The forest was full of small birds, of three or four different species, which were perfectly fearless; one little fellow alighted on my cap as I was sitting under a tree, and sang long and melodiously: another and still smaller species, of a black colour spotted with yellow, was numerous, and sang very sweetly; its notes were varied, but approximated more nearly to the song of our blackbird; occasionally a note or two resembled the lark. Hawks, too, were numerous, and might be seen on almost all the dead trees, in pairs. Along the sea-coast were to be seen the marks of their ravages upon the smaller birds. The sea-birds were very numerous on the opposite side of the island, setting upon the cliffs or hovering over the islet."

On the western side of the Auckland Island the under-brush and young trees are exceedingly thick. Dr. Holmes remarks that it was impossible to penetrate; that he was occupied fully an hour in making

his way for a hundred yards, where to all appearance a human step had never before trodden. There was not a vestige of a track; old trees were strewn about irregularly, sometimes kept erect by the pressure on all sides. Some trees were seen upwards of 70 feet in height, although the generality were only from fifteen to twenty; every part of the island was densely covered with vegetation; the soil, from the decomposition of vegetable matter, had acquired considerable richness; specimens of all the plants were collected. The botany of these islands is nearly allied to that of New Zealand, and will be found treated of in the Botanical Report to which I would refer. Some species resembling the tropical plants were found here, viz. the coffeaceous plants.

These islands have in many places the appearance of having been raised directly from the sea; the cliffs consist of basalt, and were generally from 50 to 90 feet perpendicular.

The Auckland Islands are the resort of whalers for the purpose of refitting and awaiting the whaling season, which occurs here in the months of April and May. Near the watering place a commodious hut has been erected by a French whaler. Near by was another in ruins, and close to it the grave of a French sailor, whose name was inscribed on a wooden cross erected over it. Some attempts at forming a garden were observed at one of the points of Sarah's Bosom, and turnips, cabbages, and potatoes were growing finely, which, if left undisturbed, will soon cover this portion of the island; to these a few onions were added. Besides the birds, the only living creature was a small mouse, one of which Dr. Holmes caught: it made no attempt to get out of his way, and seemed to have no fear when taken; being consigned to a pocket, he soon contrived to escape. Many of the smaller islands of this group were visited; they closely resemble the larger one. Penguins were numerous, and of a variety of colours.

These isles have a picturesque, wild, steep, and basaltic appearance: the highest peak was estimated to be 800 feet; the smaller has a less elevation; the general aspect of the land resembles the region around Cape Horn. The harbour of Sarah's Bosom is not the most secure; that of Lawrie's is protected from all winds, and has a large and fine streamlet of water at its head. The rocks are covered with limpets, and small fish of many varieties are caught in quantities among the kelp. The crew enjoyed themselves on chowders and fries. No geese were seen, and the only game observed were a few grey ducks, snipe, cormorants, and the common shag. The land birds are excellent eating, especially the hawks; and on the whole it is a very desirable place at which to refit.

On the 9th of March they had finished, and were prepared for sea, but the weather was threatening and caused them to delay. The magnetic dip was found to be 73° 47′ 30″ S. A whaler, under Portuguese colours, but commanded by an Englishman, arrived and anchored in

Lawrie's Cove, to await the coming of the whales. The night proved stormy; the wind at 10.30 from the north-east, blowing very heavy in puffs. Towards noon it moderated, and at 2 p.m. they got under way, with a light breeze from the north-west, and stood to sea.

The latitude of Sarah's Bosom is 50° 38′ S.; the longitude 165° 28′ E.

On the 12th no current was found; latitude 49° 27′ S., longitude 168° 13′ E. The weather experienced from this port to New Zealand was very similar to that in passing from Cape Horn to Valparaiso; northerly winds with mist and fog prevailing, with a heavy sea. On the 17th they fell in with the whale-ship *Mary and Martha*, of Plymouth, Coffin, master, who informed them that there were at least one hundred whale-ships cruising in the neighbouring seas; of these several were seen. This will give some idea of the number of vessels employed, and how great a capital is engaged in this business.

On the 18th they had a gale from north-north-west, which lasted through the day, moderating at sunset. They were in latitude 43° 02′ S., longitude, by chronometer, 175° 24′ E. The barometer sank to 29·30 in. A current was experienced setting north-west, in the direction of Cook's Straits.

On the 20th, in latitude 41° S., longitude 177° E., the current was found setting north-east by north, half a mile per hour. On the 22nd and 23rd they experienced a heavy gale from the south-east, when they were in longitude 179° 35′ E. and latitude 37° 52′ S. During the morning of the latter day the wind hauled to the south-south-west; the barometer, at 3 a.m., stood at 29·10 in.; the weather cleared, with the wind at south-west.

On the 26th they reached and anchored in the river Kawa-Kawa, in the Bay of Islands, off the American consul's, about three miles above its mouth. Many vessels were passed lying at anchor off the town of Kororarika. Here they found the tender *Flying Fish*, all well.

The cruise of the latter will now be taken up from the 1st of January, on which day she parted company with the *Vincennes*, in consequence of having carried away a gaff, and being obliged to shorten sail, in doing which their jib-stay got adrift, and carried away the squaresail-yard before it could be secured. The vessel was in the meantime exposed to a heavy sea beating over her, and at midnight they were compelled to heave-to. They then steered for the first rendezvous, Macquarie Island, where they arrived on the 10th, in the afternoon, and saw the *Peacock*, but it becoming thick, they were not seen by that ship.

On the 11th, Acting Master Sinclair landed for the purpose of placing a signal on the island, agreeably to instructions. The landing was found difficult and dangerous, and their description of the island agrees with that heretofore given of it from the notes of Mr. Eld, as being dreary and inhospitable. Large numbers of penguins and small green and yellow paroquets were seen. Near where they landed they saw about

twenty huge sea-elephants basking on the rocks, which did not seem to heed them; when disturbed they would only throw their carcasses over, open their mouths, utter a loud growl, and go to sleep again; no measurement was taken of them, and one which was killed could not be taken in the boat. The soil was soft and spongy, yielding to the pressure of the feet. The staff and signal being planted, they returned on board, and now passed the surf without difficulty.

On the 12th they put away for the next rendezvous, Emerald Isle. They reached its position on the 14th, but nothing was seen of it; the weather was thick.

On the 16th they kept off to the southward, with the wind from the south-west, accompanied with sleet and snow. In latitude 61° S., longitude 164° E., they saw the first ice. The next day, the 19th of January, the water was very much discoloured; got a cast of the lead in 90 fathoms: no bottom. Passed a number of icebergs that were all flat on the top, with perpendicular sides.

On the 21st they made the icy barrier, in longitude 159° 36′ E. and latitude 65° 20′ S. From the number of icebergs and the frequency of snow-squalls, they found great danger in running through them, although the water was quite smooth.

On the 22nd the weather proved pleasant, and they followed the trend of the ice. The ice-islands still showed flat tops and perpendicular sides, and there were a number of birds, seals and whales around them. They were at noon in longitude 158° 27′ E. On this day they were close by an iceberg, from the main body of which a large mass fell with a noise like thunder; the snow flying into the air resembled smoke, and the swell produced by the immersion of the fragment caused the schooner to roll water in on her deck. A number of large penguins were in sight, differing from any they had heretofore seen.

On the 23rd the weather was pleasant, and they had light winds from the southward and westward. Longitude 157° 49′ E., latitude 65° 58′ S. They continued coasting along the ice in search of an opening. At 8 p.m. they discovered several dark spots which had the appearance of rocks, and on approaching the margin of the ice they could make them out to be such with their glasses, but they were situated too far within the field-ice for a boat to get near them. This day being fine, an opportunity was afforded of drying the deck and clothes, and searing the seams with a hot iron. The vessel had been very wet, and her decks leaked badly, notwithstanding the thorough calking and repairs she had received at Sydney; the crew were almost constantly wet, below as well as above deck.

On the 24th they were obliged to steer again to the northward, in consequence of making the barrier ahead. Sea-lions were seen on the ice. They continued to follow the barrier, which trended north-north-east; the compasses were very sluggish. On the 26th and 27th the

weather became bad, with the wind to the northward and westward, accompanied by a heavy fall of snow: in the evening of the latter day the wind hauled to the southward and westward, and brought clear weather. The 28th passed with clear weather, and several seals were about them.

The 29th was thick and snowy, with a north-east wind; passed through quantities of drift-ice, and by 2.30 it had become so thick as to render a continuance of their course perilous; at 7 p.m. they again made the solid barrier, when it was blowing a stiff gale; at 9.30 discovered the ice ahead and on both beams; wore round to the northward and eastward, to retrace their steps; it was not long before they discovered a chain of ice-islands ahead, apparently connected by solid ice; about midnight a passage was discovered between two icebergs through which they passed; it was now blowing a heavy gale, and having gained the open sea they attempted to reef the foresail, but were unequal to the task (four of the men being on the sick-list), and were compelled to lay-to under the whole sail, which caused the vessel to labour very much, as well as to leak a great deal, and endangered her safety by making her fly into the wind, and get a sternboard in a high sea.

On the 30th, in the morning, the gale abated, and the weather became more pleasant than they had experienced for a number of days. They had reached the longitude of 150° 16′ E., latitude 65° 15′ S. On this day they again passed into blue water.

31st of January was thick with snow; a north wind and a heavy sea.

1st of February, they were running among ice until they sighted the barrier, when they again hauled to the northward; a moderate gale blowing, with thick weather and a heavy sea, they were obliged to heave-to.

On the 2nd and 3rd they were coasting the ice. In the afternoon of the 3rd they again had bad weather, which made it necessary to bring-to; surrounded by icebergs and drift-ice; the latter, in case of striking, would have seriously injured the tender. The icebergs seen on these days had the appearance of recent formation; the tops flat, the sides perpendicular, and not worn by the action of the sea.

On the 4th the gale continued, and the sea had risen to an extraordinary height; the weather was so thick that an iceberg could not be seen further than twice the length of the vessel. The tender was under too much sail, which caused her to labour dreadfully, in consequence of which she leaked in such a manner as to make it necessary to keep the pumps going almost continually. When they were stopped for a short time to rest the men, the water increased so as to reach the cabin floor; the water came through the seams forward in such quantities as to wet every bed and article of clothing on the berth-deck.

This was a great addition to the labour and discomfort of the crew, now reduced by sickness to four men, and the strength of these much impaired by previous sickness, excessive labour, and almost constant exposure. To relieve their situation as much as possible, Lieutenant Pinkney ordered them to make use of the cabin in common with the officers. To ease the pitching of the vessel, a quantity of coal was shifted aft; but although this was a partial relief, yet as she had too much sail on her, which they had been unable to reduce at the commencement of the gale, it was not sufficient to make her easy.

On the 5th the gale began to abate, when the crew, through one of their number, presented a communication to Lieutenant Pinkney, of which the following is a copy.

(*Copy.*)

"We, the undersigned, the crew of the schooner *Flying-Fish*, wish to let you know that we are in a most deplorable condition: the bedclothes are all wet; we have no place to lie down in; we have not had a dry stitch of clothes for seven days; four of our number are very sick; and we, the few remaining number, can hold out no longer; we hope you will take it into consideration, and relieve us from what must terminate in our death.

(Signed)	A. Murray.	Thomas Darling.
	John Anderson.	James Daniels.
	F. Beale.	Joseph.
	James Darling.	John H. Weaver.

"To Lieutenant Pinkney,
U.S. Schooner *Flying Fish*."

On the receipt of this appeal, Lieutenant Pinkney addressed an order to the officers, a copy of which follows.

U.S. Schooner *Flying-Fish*,
Lat. 66° S., long. 143° E., *Feb. 5th*, 1840.

"Gentlemen,—You will furnish me with your opinion, and the reasons which induced that opinion, of the propriety of any longer endeavouring to accomplish that part of the accompanying order, which refers to penetrating to the south.

I am respectfully, etc.,
R. F. Pinkney,
Lieutenant-Commandant.

"To Acting Master George T. Sinclair.
Passed Midshipman William May.
Passed Midshipman George W. Harrison.

(*Copy of Reply.*)

U.S. Schooner *Flying-Fish*,
Lat. 66° S., long. 142° E., *Feb. 5th*, 1840.

"Sir,—Agreeably to your order of this date, we, the undersigned officers, have to express our most thorough conviction that the condition of this vessel's crew, and the vessel, loudly demand an immediate return to milder latitudes.

"The causes of this opinion are these: that the crew of this vessel, consisting of fifteen persons (four officers and eleven men), even if well, are entirely inadequate to her safe management; but five are now confined to sick beds (one a servant), one of them is in a very critical state of health, and three others dragging out upon duty, complaining, and under medical treatment. Out of four nominally performing duty, one of them, the cook, is totally unfit to a turn at the helm, and another cannot be trusted without the closest watching; indeed, so deficient in force are we, that in the gale of yesterday and the day before, and on a previous occasion, when it became extremely necessary to reef the foresail, the men were so deficient in physical strength as to make it impossible to accomplish it.

"The crew's apartment is in the most deplorable state, leaking like a sieve, all their beds being wet, their clothes on them being so, even to their under-flannels, for *one week*, and without a dry change on hand, and no prospect of having one; so miserable is their situation, that at length you have been compelled to allot them the cabin, in common with us, for the purpose of cooking, eating and sleeping.

"Furthermore, Sir, in the gale now abating, we find that nearly constant application to the pump is barely sufficient to keep the water from flooding the cabin floor, evidently having started a leak. Notwithstanding this, the condition of the crew is more imperative, much more so in this, our recommendation, for a return to the northward; in fact, we would cheerfully continue to the southward if we had a proper crew.

"Lastly, understanding that the crew, through one of their body, have waited upon you, and by written application also stated their inability to live through these hardships much longer, and begging your return.

We are, respectfully, your obedient servants,

(Signed) George T. Sinclair, *Acting Master*.
William May,
George W. Harrison, *Passed Midshipmen*.

"Lieut-Com. R. F. Pinkney, Commanding
U.S. Schooner *Flying Fish*."

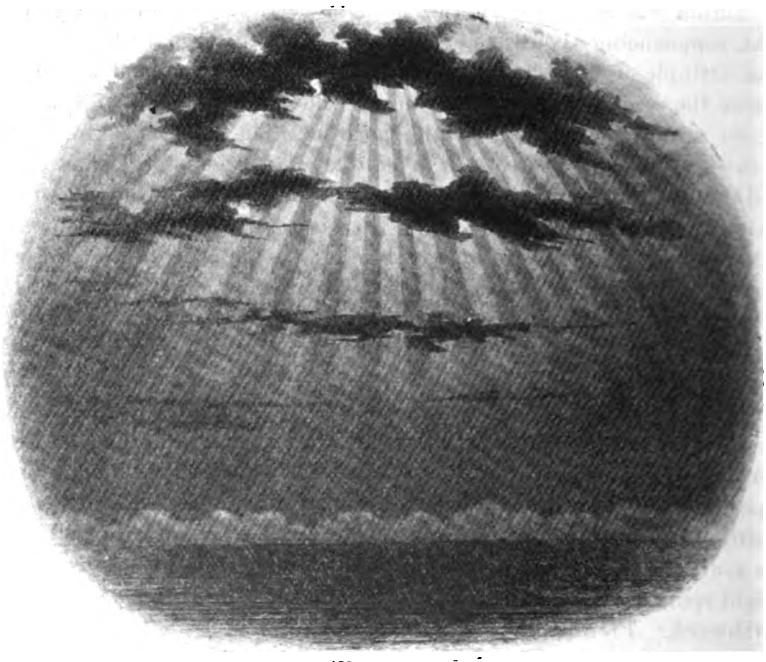
Lieutenant Pinkney, in accordance with this opinion, and his own conviction of the necessity of an immediate return to milder latitudes, as the only means of restoring the sick and preserving those on duty, who were then incapable of managing the vessel without the assistance of the officers, deemed it his duty to steer for the north, which he accordingly did.

The 6th and 7th continued thick, with occasional squalls. On the 8th the weather again broke up, when they had several hours of sunshine, which proved of great benefit to the sick. Lieutenant Pinkney was enabled to come again on deck, who had scarcely been able to quit his berth, since leaving Macquarie Island, from sickness. They had reached the longitude of 139° 45′ E., latitude 61° S. At 11 p.m. the aurora was seen; it was first visible in the south-east quarter, in spots resembling pale moonlight, extending to the zenith, from whence it diverged in rays, some of which reached the horizon, but the greatest number terminated at an altitude of twenty-five or thirty degrees. On the 9th the aurora was also seen in the west, in vertical rays of pale yellow light, commencing about five degrees above the horizon, and extending to an altitude of 30°. After a short time it disappeared, and was again seen in the zenith, radiating in lines to the north-east and west, reaching to within ten degrees of the horizon. The wind was from the southward. Temperature, 34°. The following five days they had thick weather, and nothing occurred until the evening of the 14th, when they again had a display of the aurora, the coruscations were frequent and brilliant, but did not exhibit any different form, until after midnight, when it appeared in arches reaching nearly to the horizon, at from 45° to 73° of altitude, and composed of short perpendicular lines, blending at one moment into a sheet of misty light and then breaking out into brighter lines, some of which were broad. It then again shifted to the zenith, with radiations extending in every direction in straight and wavy lines. The changes were incessant, but not shooting. On the morning of the 15th they again had a display of the aurora. It first appeared in the southern heavens at an altitude of 45°, flashing to the zenith, where it disappeared. After midnight it was again visible in the southern quarter, at about 30° of altitude. It finally centred in a bright spot, which changed into a crescent, with the rounded side to the northward. From this feathery-edged rays of pale orange-colour branched off in every direction, over which the prismatic colours seemed to flit in rapid succession. The rays would sometimes fold into one another like a fan, and reach the horizon in one direction, while in another they were drawn up to the zenith, again to burst forth in repetitions, until lost in daylight. On the 19th the aurora again appeared in an arch of 15° altitude.

They passed the last icebergs in latitude 55° 30′ S., longitude 145° 30′ E.

On the 22nd they spoke a French whaler from Hobart Town, who expressed much surprise at finding so small a vessel in such high latitudes. The captain sent a boat on board, and invited them to "soup" with him.

On the 23rd they made the southern island of New Zealand. On the 1st of March they experienced a most violent gale. The wind about noon on the 29th of February hauled to the southward and eastward, and by midnight it blew a gale, hauling to the eastward until about 8 p.m., when its violence moderated. Their latitude was 40° S., longitude 178° 30′ E. For several days previous to this a noise was heard about the heel of the mainmast. An examination was had, and the conclusion arrived at that it worked in the step, the wedges in the partners having been driven without obviating it. On the 9th of March they arrived at the Bay of Islands, where they found the gentlemen



AURORA AUSTRALIS.

who had gone there to pursue their researches in natural history awaiting our arrival.

The *Vincennes* was left on the 21st of February on her way north. On the 22nd strong gales from the west-north-west, with snow-squalls,

prevailed, and we continued to pass numerous ice-islands. The Aurora Australis had this night a beautiful and novel appearance. Black clouds were passing rapidly over the sky; an orange glow of light seemed to cover the heavens, emanating from a point over which flitted rays of the prismatic colours directed towards the horizon, lighting up both edges of the clouds and throwing them into bold relief. The rays seemed to dart simultaneously towards the horizon, on reaching which they would seem to be gathered, as if by magic, towards the centre and slowly vanish, to reappear again and fold up. I made a sketch of this appearance, which may in some measure convey an idea of it.

Strong gales continued until the 27th, with thick misty weather. In the latitude of 53° S. and longitude 120 °25′ E., we passed the last iceberg; the sea exhibited much phosphorescence; the temperature of the water was 46°.

On the 28th we found our variation 1° easterly, in the longitude of 131° 50′ E., latitude 50° 30′ S.; and in attempting to get a deep-sea sounding of 850 fathoms we lost our Six's thermometer, by the wire parting. The sea was a deep-blue; the temperature 45°. We found a current setting west-north-west three-fourths of a knot per hour. The white object was seen at the depth of fifteen fathoms.

On the 1st of March we had reached the latitude of the Royal Company's Isles, and I continued to run in nearly the same parallel for eight degrees of longitude, without seeing any signs of the supposed land. Having sailed far to the eastward of their supposed position, I again hauled to the northward to proceed to Hobart Town, Van Dieman's Land, to fill up our water. We now saw a sail, the first during sixty days, which made us feel as if we were returning to a habitable part of the globe. This night we had a brilliant display of the Aurora Australis, resembling that seen on the 9th of February, with this difference, that it was seen to the southward, extending from east-south-east to west-south-west.

On the 5th of March the wind headed us off our course to Hobart Town. I then determined to proceed direct to Sydney, and thus be enabled to communicate as speedily as possible with the United States. The con sideration of getting intelligence respecting the other vessels also led to this determination. I felt, in truth, forebodings that all was not well, from not having met any of the vessels at the appointed rendezvous along the icy barrier; and I was anxious for their safety, after the severe gale of the 28th of January.

Having reached a lower latitude, the weather had now become pleasant, and we could dispense with our winter clothing—a relief which the whole of the crew seemed to enjoy. It was the reverse with me; I had a feeling of exhaustion and lassitude that I could not account for, and the least exertion caused me much fatigue.

On the 9th we reached the latitude of Cape Howe, and were seventy miles to the eastward of it. We there experienced a rise in the temperature of the water, six degrees in less than an hour.

On the 10th, when off Cape Jervis, and about forty miles to the eastward of it, we again changed the temperature from 68° to 73° as we steered in for the land to the northward, but on hauling to the eastward it again fell to 68°. A strong southerly current has been long known to exist along this coast; and I feel well satisfied that the thermometer is a good guide in making the passage from the southward. The coasting vessels, as I was informed at Sydney, had frequently made long passages from Van Diemen's Land and South Australia, which I have but little doubt is owing to the prevalence of this minor Gulf Stream, the position of which the use of the thermometer will clearly indicate. This current will be noticed particularly in the chapter on currents. Its width no doubt varies with the season.

On the 11th of March, at noon, we passed the Heads of Port Jackson, and took a pilot. We were, as a body, in better condition than when we left Sydney three months before.

In an hour afterwards we dropped our anchor in Farm Cove, off Fort Macquarie. Our reception was flattering; scarcely was our anchor well down before many of our friends came on board to bid us welcome; and we felt ten-fold that kind hospitality which on our former visit we had first become acquainted with. They appeared to rejoice in our success as if we had been their countrymen.

During our absence from Sydney many improvements had taken place. The storehouses for the deposit of grain on an island in the harbour were in rapid progress; the new Government House nearly completed, and the foundation of an Exchange laid; besides this, many improvements in town that were then in progress had been completed; and the rapidity with which these works had been accomplished strongly reminded me of similar operations at home.

The country was looking quite green and pretty; indeed, the sail up the noble harbour was truly beautiful; it wore quite a different face from its former parched appearance, the rains having been abundant during our absence.

Observations were obtained for the rates of our chronometers, and the magnetic needles again experimented with.

On overhauling my ship, the fore-topmast was found to be slightly sprung.

It was with great pleasure I learned the safety of the *Peacock*; for that vessel had occupied my thoughts more than the others, on account of the condition in which she left Sydney. All on board of her were well, and the vessel was undergoing repairs in Mossman's Cove, one of the many which this harbour forms. These coves may be termed wet-docks affording as they do every facility for the repair of vessels of

any size. They are more like artificial than natural basins, and are secure against any wind. There is no port in the world that offers so many natural advantages as Port Jackson for a great naval power. We had many things to relate to each other; among others, the particulars of the accident that befell the *Peacock* that has already been noticed. The return of that vessel to this port now claims our attention.

On the 28th of January, their sick-list had increased to thirteen, more in consequence of the fatigue the men had undergone, than from any disease.

On the 29th they experienced strong gales from the north-west, which continued to increase until midnight, after which the weather moderated. The ship during this gale was in latitude 61° 20′ S., and longitude 154° 09′ E. This gale is remarkable, in consequence of its blowing in a contrary direction to that which the *Vincennes* experienced on the same day; while the former had it from the north-west, the latter had it from south-east. Their distance apart was 450 miles, in a north-east direction.

On the 1st of February the weather was stormy until towards evening, when it moderated and cleared off, with the wind to the north-west, and gave them a view of the Aurora Australis lighting up the southern portion of the horizon. Rays were thrown out in different directions, some reaching an altitude of 30°, others of 40°, whilst others again almost spanned the heavens.

On the 2nd they had another display of the aurora, but contrary to that of the previous day, it was first seen at an altitude of 70°, diverging towards the horizon, from east-south-east to the west-south-west-by-south, before it disappeared. The point from which the rays diverged reached the zenith.

On the 4th they made Macquarie Island, and shortly after passing it experienced another gale from north-west to south-west, which caused them much anxiety for their rudder, which thus far had answered well, although attention was necessary to prevent strain upon it. Strong gales yet continued. On the 5th they had a faint display of the aurora.

On the 7th of February the weather had become less boisterous, and having reached latitude 49° S., longitude 155° 23′ E., the Aurora Australis again appeared. It was first seen in the north, and gradually spread its coruscations over the whole heavens; the rays and beams of light radiating from nearly all points of the horizon to the zenith, where their distinctive outlines were lost in a bright glow of light, which was encircled by successive flashes resembling those of heat lightning on a sultry summer night; these formed a luminous arc in the southern sky, about 20° in altitude, from the upper part of which rays were continually flashing towards the zenith; light showers of rain finally shut it out from view. On the same night, between one and

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three, the aurora burst out from the south-western horizon, streaming up and concentrating in the zenith, and attended with quick flashes of every variety of tint. The wind was moderate from the south-west, and a squall of hail passed at the time. In latitude 47° S. they first encountered phosphorescence in the water. On the 17th they made the land of New South Wales, and continued to experience a variety of weather until the 21st, when they arrived off, and anchored within, the Heads of Port Jackson.

The next day they proceeded up the harbour and anchored off Sydney Cove. The ship was much shattered, but her officers and crew all in good health. Here they were kindly received, and no time was lost in proceeding to make the necessary repairs. The collector was kind enough to give them permission to land everything that might be necessary, when and where they pleased. The powder and fire-works were received in the public magazine, and when called for were politely sent in a government boat, free of expense. The railway for merchant-vessels was found too light to trust the *Peacock* upon it. Mossman's Cove, on the north shore, was then resorted to, not only as a convenient place for making the necessary repairs, but as affording more security for the crew against the crimps and rum-shops.

The day after my arrival I visited the *Peacock* in order to examine into her condition, and could not withhold my astonishment that she had been able, after undergoing such damage, to reach a distant port. The visible injuries have already been stated, in speaking of her accident. On their arrival at Sydney, it was found that her stem had been chafed to within one and a half inches of her wood ends, and strained throughout. After a full examination of the circumstances, I felt it a duty I owe to Captain Hudson, as well as to his officers and crew, to state that I am well satisfied, that his coolness, decision and seamanship, with the good conduct of his officers and men in the perilous situation in which they were placed, are worthy of the highest encomiums. The preservation of the ship and crew, and her subsequent navigation to a distant port, reflect the highest credit upon her commander and upon the service to which he belongs.

Sydney was now much crowded with people, and several balls were given, to which we had the honour of an invitation. That of the St. Patrick Society was attended by the chief people in the neighbourhood of Sydney, including the governor and most of the officers of the crown. It was given in the New Court-house, and was a handsome and well-conducted entertainment. Two military bands were in attendance; quadrilles and country dances followed each other in rapid succession; rooms were provided for cards, refreshments, teas, lemonade, etc.; and towards the close of the evening the company was ushered in to an elegant supper, which was partaken of standing.

I was struck with the beauty and general appearance of the ladies,

though I was informed that many of the belles were absent. The style of the party was neither English nor American, but something between the two. I scarcely need remark that we were all much gratified and pleased. The hospitality and kindness shown us were of that kind that made us feel truly welcome.

Our last week at Sydney was spent in a round of pleasure, and the attention we met with being entirely unexpected was doubly gratifying to us.

EXTRACT FROM "VOYAGE AU POLE SUD, ETC., SUR LES CORVETTES 'L'ASTROLABE' ET 'LA ZÉLÉE,' SOUS LE COMMANDEMENT DE M. J. DUMONT-D'URVILLE, CAPITAINE DE VAISSEAU." VOL. VIII., 1845.

CHAPTER LIX.

Voyage towards the Antarctic Pole.—Discovery of Adélie Land.

1840, *Jan.* 1.—At 4 o'clock in the morning we were under sail. Captain Moriarty wished to pilot us himself, "in order," as he said, "to have a few more minutes with you." The breeze was favourable and I was eager to take advantage of it. Just at this moment the announcement came that M. Goupil had breathed his last during the night. I knew how much this young artist was beloved by all his companions. I knew, too, that all the officers of the expedition were most desirous of spending one more day on shore in order to pay the last honours to his remains; but on the other hand our departure had already been very much delayed, and we had not a moment to lose in getting to sea in order to reach the ice in the favourable season. Besides, our crews, already much reduced in numbers, had been reinforced with much difficulty by some English sailors, who were quite ready to desert, and threatened to leave us every moment. All these considerations determined me to continue my voyage, notwithstanding my own strong wish to render the last homage to the unfortunate Goupil, whose zeal and talent I had much appreciated. Also, to my great regret, our corvettes, being under full sail, were drifting out of the roads. For one instant I conceived the hope that I might get out of the river that same day, but soon the wind, till then uncertain, veered to the S.S.E. and began to blow strongly.

From that moment it was useless to think of battling against contrary winds to gain the open sea. So I decided to drop anchor again in the bed of the river, some miles from the harbour, and postpone our start till the next day. Several boats came alongside the *Astrolabe* during the day, bringing planks which had been forgotten; they told us that the funeral of our unfortunate fellow-traveller was to take place in three days. The officers of the English garrison had themselves fixed the ceremonial and decided on the honours to be paid. It was therefore quite unnecessary for our boats to go alongside the quays again that day; we could only mingle our sincere regrets with those of

our invalids who were on shore, for whom was reserved the melancholy satisfaction of accompanying to his last resting-place this latest victim of the epidemic. Nevertheless I granted permission that evening to MM. Gervaize and Dumoutier to go ashore, since they desired to do so, on the express condition that they should be on board the next morning by 4 o'clock.

M. Goupil, artist to the expedition, was scarcely twenty-five years of age; his death, although expected, left a profound impression upon us all; "for" said M. Dubouzet, "no one could have failed to appreciate the fine qualities which he possessed. Everyone beheld with distress a young man so remarkably talented cut off in the flower of his age, after a long and difficult voyage, to which the passion of art and travel had led him to sacrifice everything. Never," added M. Dubouzet, "was his noble character so markedly shown as during his long and severe sufferings, which he bore with so much courage and resignation, dictating his last wishes with the utmost calm. To the last moment his thoughts were with his family and his friends; he gave souvenirs to each of us, expressing the deepest gratitude to all those who attended him."

Jan. 2.—At 2 o'clock the next morning the pilot came alongside our corvettes and gave the signal for departure, notwithstanding the calm which prevailed. Thanks to the current of the river we soon reached the great Bay of Tempests, a magnificent basin where the shallow water allows of an anchorage in any part, and where an entire fleet could go freely through its evolutions. The wind, till then uncertain, became steady in the north-east, but it was possible to tack. We dismissed the pilot and ran along the shore to the open sea, the great swell of which made itself felt even where we were.

Jan. 3.—Not till the next morning did we lose sight of the Tasmanian shore and begin to run southwards. If the reader will kindly recall the chapter placed at the opening of the second volume of this work, in which I have attempted to summarise the results obtained by various navigators in reaching the glacial regions, he will see that there still remained on the zone of the South Pole a vast space to be explored: it was that which is bounded by 120° and 160° E. long.: and it was there that I wished to take our corvettes on leaving Hobart Town. I had no idea at this time that an English merchant ship had preceded us by a year in those latitudes, and I had as yet no knowledge of the Balleny Islands nor of Sabrina Land, the discovery of which had been made a year before our appearance in these regions. In undertaking the responsibility of a fresh attempt to penetrate into the ice, my intention was only to make a new exploration along the pack-ice. I simply wished to make some point to the South of Tasmania, determine the parallel below which I met solid ice, and then direct my course either to the Auckland Islands or to one of the New Zealand ports: while the *Zélée*

should return on her course to Hobart Town to take up our sick, and then rejoin us at some place on which I should decide.

Everyone knew that the portion of the polar circle stretching directly to the south of Tasmania had not been explored by any navigator. In tracing on a map the courses of the different travellers who had tried to penetrate the ice, I had seen that the route of Captain Cook alone traversed this space; but even so, the celebrated English navigator had never tried to penetrate into these latitudes where he had remained below the 60th parallel. By advancing from this side I hoped to get as far south as it was possible to do. My crews, although overworked, were full of spirit, and already accustomed to this kind of navigation; I knew, therefore, that it would require some wholly impassable obstacle to stop me. Without counting too much beforehand on the future issue of my fresh attempt, I had resolved to make it in any case as fruitful as possible in the interests of physical science. An important discovery remained to be made, the position of the magnetic pole, the knowledge of which is so important for the solution of the great problem respecting the laws of terrestrial magnetism. From the outset I had always wished to shape my course with this end in view. I knew also that the most profitable observations of this nature would be those made on the magnetic meridian itself. I sought, therefore, to keep our corvettes on this direction, giving orders to hold our course always south by the compass whenever the wind would permit.

Our voyage was begun under the most contrary auspices; steady winds from the south blew dead against us, while the currents carried us to the east, and forced us to sail close to the wind for fear of losing our course. A strong swell, as much as four to five metres high, made our ships roll, and produced great discomfort; and lastly, we had hardly left the shore four days before M. Dumoutier reported nine men on the sick list. Since our departure, however, there had been a continual supply of fresh food for the crew, who were not at all overworked, and I had made it a rule to give them as little to do as possible. In a few days I might have need of all their strength! A heavy responsibility weighed on me; but before throwing myself into an enterprise so hazardous I had reckoned on the courage of my men, and I was sure that it would not fail me.

Jan. 8.—The further we advance south the lower becomes the temperature; we sail amid a flock of albatross, which never leaves us. Numerous whales are spouting round us, but it seems as if this variety is not that which is hunted by fishermen, for a whaler passing at a short distance from us continues her course eastwards without stopping.

Some moments of calm allowed the two corvettes to communicate with each other to-day. One of the boats of the *Zélée*, commanded by M. Gaillard, managed to come alongside the *Astrolabe*, notwithstanding

the swell. This midshipman came to reclaim a dipping-needle which had been declared faulty by M. Dumoulin, and was of no use whatever; also to consult with the mechanician as to the nature of the observations which could be made on the *Zélée*, and what he considered advantageous in these latitudes. Every day MM. Dumoulin and Coupvent took at intervals numerous observations of inclination with an excellent instrument made by M. Gambey. I should add that M. Gaillard, with all his efforts, was never able to turn to account the dip-needle which he had come to reclaim. It is to be regretted that our two corvettes, on leaving France, were not provided with instruments which could have been compared with each other, for observations of this kind made at sea are too difficult and uncertain for science to profit much by a comparison of them. Observations should be made simultaneously on board two ships sailing together.

I took advantage of this circumstance to question M. Gaillard as to the sanitary state of his ship; he told me that the *Zélée* had seven men on the sick list: of these, three appeared to be seriously ill. The dysentery from which they were suffering seemed to have taken a more severe form since they had left Hobart Town. I greatly regretted these relapses, but the men had only been taken on board the *Zélée* after consultation with M. Hombron, and when their recovery was sufficiently advanced to allow them to go to sea again.

Jan. 11.—On the 11th we had passed the 51st parallel of south latitude; we therefore found ourselves in the position assigned by several hydrographers to the Royal-Company Island. Notwithstanding careful scrutiny and the most favourable horizon we saw no land. It is probable that this island, if it exist, is marked wrongly on the maps. Besides, it must often happen in seasons when the glacial regions are favoured by a very hot summer, that great breaking up of the ice occurs, and then the icebergs have been frequently carried as far as the 50th parallel of south latitude and recorded as new discoveries. According to the quantity of light which they receive, the ice-islands often display strange hues, which give them the appearance of isolated rocks.

The albatrosses, which had never left us from Hobart Town onwards, disappeared about the 50th degree lat. The wind also began to blow strongly; for two days we were obliged to lay-to under the try-sail with a very high sea, and our ships laboured heavily. The *Astrolabe* had only two men on the sick list, but the *Zélée* had still three sick men whose condition gave cause for great anxiety. This bad weather could not but be harmful to them; indeed, after one of the worst gales we had undergone, a seaman of the first class, named Pousson, breathed his last. "This man," said M. Jacquinet, "had only felt slight colic a few days before we left Hobart Town. When we quitted that English colony he gave no cause for anxiety, and he was not in a condition to

need a long stay in hospital; but since we got out to sea the dysentery had made rapid progress, and at the end of very few days all medical resources were unavailing." "We lost in him," adds M. Dubouzet, "one of our best sailors." The unfortunate man had embarked at Valparaiso on the very day of our departure; since then he had filled for nearly two years the post of coxswain of the ship's boat, to the satisfaction of all his superiors.

That day we were assailed by snow squalls, which increased still more the force of the wind. The temperature of the sea had also suddenly sunk, and thousands of petrels of all colours surrounded our ships. These signs seemed to indicate the approach of pack-ice, as at the time of our first attempt to penetrate into the ice: we had scarcely reached 58° lat., and already we were all dreading to see our course blocked. However, next morning the sea-birds became less numerous round our ships, the wind had gone down and the temperature was milder. It was two years before, on a similar day and nearly in the same latitudes, that our crew had seen for the first time floating ice. This coincidence did not escape them, and, in comparing the two situations, they expressed the hope of being more fortunate in this new enterprise; this hope was to be of short duration.

Jan. 16.—At 3.25 a.m. the watch signalled the first ice, which was quite insignificant. It was a piece of ice (*glaçon*) of small dimensions, which was in no way remarkable, and would certainly have passed our corvettes unnoticed if it had not pointed to the probable approach of insuperable ice barriers. Shortly after, other masses of ice (*glaces*) showed themselves on the horizon, to the number of five or six. We came up very close to the one nearest us; it formed a mass of about 400 metres broad by about 21 high. The sloping edges showed that it had been for a long time in the open sea, where the waves, agitated by the wind, had already made large hollows in its sides. For an instant the sight of this iceberg (*glaçon*) attracted the attention of the crew, but our men had been so long accustomed to this kind of navigation, that the sight of this floating island did not long keep their attention. We had scarcely passed it before they had assumed their ordinary occupations and gave free vent to their spirits. We counted among us a dozen men who gazed for the first time on these formidable masses. They naturally became a subject of merriment to their comrades, and soon, following the example of the others, they showed in their turn no sign of wonder at the sight of the floating ice which we continually met.

The appearance of these icebergs (*glaçons*) augured no good for the future. At my first attempt we had seen the first ice at 59° lat., and we had been unable to pass the 65th parallel; to-day we had only reached the 60th degree, and I therefore naturally concluded that we should soon reach the same pack-ice (*banquises*) which had stopped us before. How-

ever, these first icebergs (*glaces*) seemed to me too large to have been formed in the pack in the open sea. I thought they must have originated rather from some land in the neighbourhood, and the result proved I had not been mistaken.

The wind continued to blow from E.N.E., but the sea had suddenly subsided and the swell barely reached us. That was a certain indication of the approach of land or of pack-ice. We all noticed this; but since no floating ice-islands were visible during the two days which followed, we continued to hope we might reach a high latitude. The cold had become very intense. The thermometer rose very little above zero. The sea birds were fewer, and at last the observations of the magnetic needle indicated that we were very near the magnetic pole, the search for which was one of the principal objects of the expedition.

Jan. 18.—On the evening of the 18th we had reached 64° S. lat. The weather was damp, the temperature fairly mild, and we were full of hope we might soon pass the 70th parallel; but at midnight we found ourselves suddenly surrounded by five enormous blocks shaped like a table. These icebergs (*glaces*) had exactly the same appearance as those we had encountered in such large numbers near the Powel Islands. From that moment my foreboding that we were near some unknown land increased; I reluctantly gave up the hope I had cherished of penetrating to a high latitude, for I thought that I should soon be stopped by the land which presumably was in front of us, and this in any case would form the nucleus of a solid and insuperable iceberg by offering a solid base for floating ice. The weather was cloudy; snow fell abundantly, and, notwithstanding the danger of sailing by night in these latitudes, we took advantage of a fair easterly breeze which was blowing to advance further to the south.

Jan. 19.—At 6 o'clock in the morning we counted 6 ice-islands floating round us. At 8 a.m. we distinguished 16. All the blocks were on the whole larger than those we had already encountered. They were all of the same shape, being flat with perpendicular sides. Their height varied from thirty to forty metres; as regards their horizontal dimensions, we noticed several which were more than 1000 metres broad, and one of them was admittedly a mile from end to end. They were all alike, and similar to those we had seen in the neighbourhood of land on our first polar expedition. There seemed to be no trace of fusion nor of decomposition; in none of them were to be seen those vast hollows formed by the sea at their edge, which imitate to perfection the arches of a bridge, especially when the light shines on them obliquely. These floating islands seemed to have been detached the night before from an ice-bound coast at a short distance.

Our corvettes were surrounded by white and grey petrels, petrels tachetés (*damiers*), some penguins, a whale, and two or three seals. This was another indication of being near land. At 9 a.m. we saw

in the E.S.E. a great black cloud which seemed stationary and had the appearance of a raised island. For a long time we followed it with our eyes, always thinking we saw some indication which would prove we had made a new discovery. But at 10 a.m. the sky, hitherto cloudy, suddenly cleared. The sun appeared in all its glory, and quickly dispersed this deceptive apparition. Towards 3 p.m. M. Gervaize, who was officer of the watch, thought he saw once more an indication of land in the east. For some time he had noticed in this direction a greyish spot which appeared stationary; but we had already been so often misled by false appearances, so frequent in these latitudes, that we had become very sceptical. M. Dumouiin, who was on the poop, occupied at the moment in taking the bearings of the different ice-islands in sight, hastily climbed into the rigging to clear up all doubt; he assured himself that the indication given by M. Gervaize referred to a cloud which, seen from the height of the mizzen top, appeared to be above the horizon. On coming down he also announced to me that right before us there was an appearance of land much more distinct and sharply cut; this was in fact Adélie Land. Thanks to this circumstance, M. Dumoulin was the first among us all to see this land. But he had been so often deceived by illusions of this kind that he was himself far from believing in his discovery, and he was one of the very last to recognise the reality of its existence.

At 6 p.m. we counted 59 great icebergs (*glaces*) round us and a great number of others in sight. The wind had quite dropped; the sea, beaten down under the weight of the enormous blocks which crowded it, was calm and smooth as a lake. The sun was shining in all its glory, and its rays, reflected on the crystal walls which surrounded us, produced a magical and charming effect. We had not a single man on the sick list. M. Dumoutier had warned me that he thought he recognised signs in some of the men of an approaching epidemic of scurvy; but happily all danger of this sort had rapidly disappeared, thanks to the precautions of the doctors. Thus our crews were full of courage and spirit and appeared happy and contented. They had been preparing for some time a ceremony similar to that practised on board ship when crossing the equator, and the actors, having asked my permission, were ready to appear on the scene as soon as we arrived at the polar circle. I have always thought that the practical jokes which the sailors are in the habit of playing off on those who cross the equator for the first time, have a good effect on board ship, where any distraction for the sailors is so rare, and where want of employment and the consequent boredom spread depression among the crew. Therefore, far from opposing the buffoonery, for which our men were preparing, I declared myself ready to be the first to submit to it; only, on account of the temperature, I forbade all throwing of water on the deck or of subjecting anyone to ablutions which are only supportable under the torrid zone. For the rest, I left

them to invent the kind of ceremony to which they wished to subject those on board the *Astrolabe*, and it will be seen later that in this respect their powers did not fail. We had attained the 66° S. lat., everything led us to hope that we should soon pass the Antarctic circle, and according to custom I was officially warned that the next day I should receive a visit from Father Antarctic. After a rain of rice and beans hurled from the top, I received a postilion mounted on a seal, who brought me the message from his fantastic sovereign. I will spare the reader the costume of this singular ambassador and the contents of his letter; I observed with pleasure that the sailors had changed the ceremony of baptism, customary on the line, to one of communion in one element, that of wine, and as this would be better for them, I had no objection to make. We all hoped that the next day we should have passed the polar circle, but the calms which succeeded the wind arrested our progress. We were at the season when the days are longest in the glacial zone, so that at 9 p.m. the sun was still above the horizon and its luminous disc set slowly behind the land, whose existence was for several of us still very doubtful. At 10.50 this luminary disappeared, and showed up the raised contour of the land in all its sharpness. Everyone had run together on to the deck to enjoy the magnificent spectacle which offered itself to our gaze. It would have been impossible indeed to paint the grandeur of the sight. The calm of night gave to the enormous masses of ice which surrounded us a grander but also a more severe aspect; all the crew watched the sun disappearing behind the land and leaving behind him a long train of light. At midnight there was still twilight, and we could easily read on the deck. The night lasted only half-an-hour; I took advantage of it to snatch some rest, postponing till the next day the task of clearing up doubts as to the existence of the land in front of us.

Jan. 20.—At 4 a.m. I counted 72 large icebergs (*glaces*) round us. I knew that during the night we had hardly changed our position, and yet among all these enormous blocks surrounding us, each with its own peculiar shape, although presenting an aspect of uniformity, I hardly recognised one of the floating islands I had noticed the night before. The sun had been up a long time, and although the atmosphere was misty its warmth could be felt, and all the icebergs (*glaces*) around us seemed to be undergoing an active disintegration. One of them, which was only a short distance from us, attracted my notice especially. Numerous streams flowed from its summit, making deep hollows in its side, and hurled themselves into the sea in cascades. The weather was magnificent; but unfortunately there was no wind; before us rose the land: one could distinguish the details of it. Its aspect was very uniform. Entirely covered with snow, it stretched from east to west and seemed to drop towards the sea by an easy incline. In the midst of the uniform greyish tint which it presented we could see no peak, no single

black spot. Thus there still remained more than one among us who doubted its existence. However, at midday all doubt vanished. A boat from the *Zélée*, which came to visit us, announced that land had been seen by those on board ever since the evening before. Less sceptical than ourselves, all the officers of the *Zélée* were already persuaded of the reality of this discovery. Unfortunately an unbroken calm prevented us from approaching it to make the matter certain. Nevertheless, joy reigned on board; henceforth the success of our enterprise was assured; for the expedition could report in any case the discovery of a new land.

The day was entirely devoted to the sports of the crew. Although we had not yet reached the polar circle, our men did not wait for that to produce the Antarctic sovereign on the bridge. They represented, as usual, all kinds of strange scenes; there was a show of mummers, a sermon, and a banquet. The whole closed with dancing and singing. The entire crew were cheery and full of fun. Indeed, since leaving Hobart Town, our men had rarely enjoyed more flourishing health. Numerous sea-birds surrounded us; we saw a great number of penguins floundering about in the water, and several fur seals, but not a single one of those giant petrels which we had found in such abundance on the icebergs (*glaces*) during our first circumpolar expedition; they used to come, when our corvettes were hemmed in the ice, and fight under our very eyes for the remains of the seals killed by our hunters. We picked up on the surface of the sea a long whitish girdle of most singular appearance. It was more than 2 metres long, round, and uniform. Later we found it was formed by an agglomeration of molluscs; we found similar girdles later on, but shorter.

Jan. 21.—Ever since we had recognised land we were impatiently awaiting a wind which should enable us to approach; at last, at 3 a.m., it rose in the S.S.E., but it was so light that we hardly made one knot. As we approached nearer we distinctly saw crevasses on the ice crust which covered the earth, giving it a very uniform grey tint. Here and there we saw deep ravines hollowed out by the water which arose from the melting of the snow; but the details of the coast were hidden from us by the islands of floating ice which, in all probability, had but lately been detached.

At last the wind settled in the S.S.E., and we began to advance rapidly; but the nearer we came the more numerous and menacing became the ice-islands. Soon they really became an alarming mass, divided by narrow, winding channels. Nevertheless, I did not hesitate to steer towards it. At 8 o'clock we were so shut in by these floating masses that I feared every minute to see our corvettes dashed to pieces on them. We were by no means free from danger, for the sea produced around these masses considerable eddies, which could not fail to bring a ship to destruction if she were for a moment sheltered from the wind

by the high cliffs of ice. In passing at their base we were well able to judge of the height which these icebergs attain. Their perpendicular walls towered above our masts; they overhung our ships, whose dimensions seemed ridiculously diminutive compared with these enormous masses. The spectacle which presented itself to our gaze was at once grand and terrifying. One could imagine oneself in the narrow streets of a city of giants. At the foot of these immense masses we perceived vast caverns hollowed out by the sea, where the waves rushed in with a roar. The sun darted oblique rays on the immense walls of ice, which resembled crystal. The effects of light and shade were truly magical and striking. From the top of these ice mountains there leaped into the sea numerous streams, caused by the apparently very active melting of the snow. We often saw in front of us two icebergs so near each other that we lost sight of the land towards which we were steering. We could then only see two straight, threatening walls rising up beside us. The orders of the officers were echoed several times by these gigantic masses, which threw the sounds of the voice from one to the other; when our eyes fell on the *Zélée*, following us at a short distance, she looked so small and her masts seemed so slender, that we could not suppress a feeling of alarm. For nearly an hour we saw nothing round us but vertical walls of ice. Then we reached a vast basin formed by the land on one side, and on the other by the chain of floating islands through which we had just passed. At midday we were not more than three or four miles from our new discovery.

The land which was in sight showed now such irregularities as it possessed; it stretched as far as one could see to south-east and north-west, and in these two directions its limits were invisible. It was entirely covered with snow, and might reach a height of 1000 to 1200 metres. Nowhere was there any striking peak. Nowhere was any spot to be seen which indicated soil, and one could almost believe that we had before us an ice-pack considerably larger than any we had met, granting the possibility of any pack attaining such a prodigious height. The shore presented everywhere a vertical cliff of ice, like those we had noticed in the floating islands we had just passed. This aspect of the coast was so like that presented by the floating icebergs (*glaces*) that we had never hesitated about their formation. Besides this, at several points along the shore we noticed a great quantity of floating ice, apparently scarcely separated from the shore where they had been formed, and only waiting for the winds and currents to gain the open sea. The higher parts of the land presented everywhere a uniform hue, reaching the sea by a gentle incline; owing to this formation we could see at a glance a considerable stretch of land. At several points we noticed that the surface of the snow which covered the land was ploughed up. One could distinguish regular waves like those

hollowed out by wind in the sand deserts. It was especially in the less sheltered places that the irregularities were more marked. At other points this ice crust seemed also traversed by ravines or hollowed by water. The sun was shining brilliantly, adding greatly to the already very imposing aspect of this mass of ice. With our glasses we were gazing curiously on this mysterious land, the existence of which no longer seemed doubtful, but which had not as yet offered any undeniable proof of it. Before long the man on the look-out thought he could distinguish a dark spot on the coast line, and hastened to announce his discovery; several officers who had run up the rigging also thought they could see the longed-for signs across a mass of floating islands which bordered the coast. But as we approached, the black spot which had been sighted suddenly disappeared. We recognised among the floating islands one which had an earthy colour, and this might have given rise to the mistake. We supposed that this was the dark spot seen by the man on the look-out. It is possible, however, that there was in this part an island or a bare summit, which might have appeared in a given direction, but which had disappeared later behind the icebergs (*glaces*) which bordered the coast. The events of the next few hours show that this hypothesis was very probable.

The wind, although light, was favourable for sailing along the coast westwards. All day was occupied in exploring it. We noticed several projecting headlands and some rather shallow bays choked by an immense quantity of floating islands; everywhere the coast presented the same aspect, terminating towards the sea in an ice-wall which rendered all landing impossible. For some time MM. Dumoulin and Coupvent, who were anxious to obtain magnetic observations more conclusive than those they had made on board, had asked me to land either on the coast or some ice-island sufficiently large to be absolutely steady. In vain during the day had I sought an opportunity to satisfy this laudable desire; all the ice-islands that we met with were inaccessible. But towards 6 p.m. one of them, having a fairly easy incline on one side, seemed to unite all the conditions necessary for this kind of work. Immediately the whale-boat was lowered in order to convey the officers who were to take their observations. In the meantime our corvettes lay-to, in order not to drift from this spot. It was at this moment that we verified irrefutably the existence of land. M. Duroch, who was officer of the watch, had already fixed his glass on a point where for a moment he thought he saw dark spots; but every mark of the sort immediately disappeared as our corvettes began to move. Suddenly, he again noticed rocks, the sombre hue of which contrasted with the whiteness of the snow, but they disappeared immediately behind the icebergs; this time, however, the land had been recognised in an unmistakable manner. I decided to have a boat got ready to go and verify this important fact. At this advanced hour of the day, the sending of

a boat to so great a distance was not without danger. Besides our boats were very inferior in sailing qualities to the whaler, which I had already dispatched to make the physical observations. However, as I was anxious to profit by the fortunate circumstances which might never occur again, I confided the large boat to M. Duroch, with the order to collect palpable fragments of our discovery. The *Zélée* also sent a boat under the command of M. Dubouzet. Like ourselves, the officers of this ship had noticed bare islets, and were also keenly anxious to go and examine them.

At 9 o'clock MM. Dumoulin and Coupvent returned on board, having finished all their observations. They had established one important fact which explained how the ice-islands, after being formed on the coast, were able to float away so rapidly. After having arranged a dip-circle on the ice where they had landed, these gentlemen had turned the *lunette d'épreuve* on to a very distant iceberg. After a very short time they perceived that the island on to which they had directed the glass had undergone a great movement. Afterwards, when they aimed at one of the points of the land, in order to know if the iceberg on which they stood (and which appeared much larger) had a movement of its own, they proved that this enormous mass was being impelled independently by a movement, which though it appeared very slight, was not the less evident to the glass. While the corvettes were lying-to I had tried to take soundings; unfortunately all our sounding-lines were almost useless. I had only been able to drop the lead to 100 fathoms without finding bottom. It is certain, since the ice on which MM. Dumoulin and Coupvent had made their observations was not resting on the earth, it is certain, I say, that the sea there is very deep.

The two boats which had gone ashore did not return till 10.30, laden with fragments of rocks detached from the shore. The following is an account of this interesting excursion from the journal of M. Dubouzet:—

"During the whole day all eyes had been fixed on the coast to try and discover something other than snow and ice. At last, when we were beginning to despair, after having passed a mass of floating islands which quite blocked out the shore, we noticed several little islets the sides of which, destitute of snow, showed us that blackish earth so ardently desired. Several minutes later we saw the large boat of the *Astrolabe* leave the corvette and start towards the shore with an officer and two naturalists. Immediately I requested Commander Jacquinot to embark me in his yawl, which he ordered to be lowered to send ashore. The *Astrolabe* boat had already got a good start of us; after 2½ hours hard rowing we reached the nearest islet. Our men were so full of ardour that they hardly noticed the effort they had just been making, in covering more than seven miles in so short a time. Going along, we passed quite close to immense ice-islands. Their perpendicular sides, eaten away by the sea, were crowned on the top by long needles of a greenish ice formed

after a thaw. Their appearance was to the last degree imposing. They seemed to form an insurmountable barrier to the east of the islets to which we were bound; and this made me think that they were perhaps fixed 80–100 fathoms down. Their height indicated about this draught of water. The sea was covered with débris of ice, which obliged us to take a very winding course. On the icebergs (*glaçons*) we noticed a crowd of penguins, who with a stupid air quietly watched us pass.

"It was nearly 9 o'clock when, to our great joy, we landed on the western part of the most westerly and the loftiest islet. The *Astrolabe's* boat had arrived a moment before, and already the men had climbed up the steep sides of this rock. They hurled down the penguins, who were much astonished to find themselves so brutally dispossessed of the island, of which they were the sole inhabitants. We also jumped on shore armed with pickaxes and hammers. The surf rendered this operation very difficult. I was forced to leave several men in the boat to look after her. I then immediately sent one of our men to unfurl the tricolour flag on this land, which no human creature had either seen or stepped on before. Following the ancient custom, faithfully kept up by the English, we took possession of it in the name of France, as well as of the adjacent coast, which the ice prevented us from approaching. Our enthusiasm and joy were such that it seemed to us we had just added a province to French territory, by this wholly pacific conquest. If the abuse which has been born of such acts of possession has caused them to be often regarded as ridiculous and worthless, in this case at any rate we believed ourselves sufficiently in the right to maintain the ancient custom in favour of our country. For we dispossessed none and our titles were incontestable. We regarded ourselves, therefore, at once as being on French soil; and there is at least this advantage that it will never raise up war against our country.

"The ceremony ended, as it should, with a libation. To the glory of France, which concerned us deeply just then, we emptied a bottle of the most generous of her wines, which one of our companions had had the presence of mind to bring with him. Never was Bordeaux wine called on to play a more worthy part; never was bottle emptied more fitly. Surrounded on all sides by eternal ice and snow, the cold was extreme. This generous liquor reacted with advantage against the rigours of the temperature. All this happened in less time than it takes to write it. We then all set to work immediately to collect everything of interest in natural history that this barren land could offer. The animal kingdom was only represented by the penguins. Notwithstanding all my search we did not find a single shell. The rock was entirely bare, and did not even offer the least trace of lichens. We found only one single seaweed, and that was dry; so it had been brought there by currents or birds. We were obliged to fall back on the mineral kingdom. Each of us took

a hammer and began to hew at the rock. But it was so hard, being of a granite nature, that we could only detach very small pieces. Happily, while wandering on the summit of the island, the sailors discovered large fragments of rock detached by frost, and these they took into our boats. In a short time we had enough to supply specimens to all our museums and to others besides. In examining them closely, I recognised a perfect resemblance between these rocks and some small fragments that we had found in the stomach of a penguin killed the evening before. These fragments could, if necessary, have given an exact idea of the geological formation of this land, if it had been impossible to go on shore there. However extraordinary may be this way of doing geology, it proves how much interest the smallest observations may have for the naturalist, often even helping him in his researches, by leading him sometimes on to the track of discoveries to which they seem to be the most foreign. The small islet (*ilot*) on which we landed is one of a group of eight or ten small islands rounded above, and all presenting pretty much the same form. These islands are separated from the nearest coast by a distance of 500–600 metres. We noticed along the shore several more tops quite bare, and one cape of which the base was also free from snow; but we noticed also a great quantity of ice which made the approach to it very difficult. All these islets, very close to each other, seemed to form a continuous chain parallel to the coast from east to west. All the ice islands, accumulated in the eastern part, which seemed to me fixed, probably cover other islets similar to those on which we had landed. It is certain that many rocks must be buried every year by enormous masses of ice, of which they form the nucleus. Perhaps even the great land in front of us was cut up by numerous channels. The hydrographical records which were made in these latitudes can have no other object than to determine the form of the glaciers at the moment of our passage without showing the contour of the coast, which must rarely be free from the thick crust covering the soil.

"We did not leave these islets till 9.30; we were entranced by the treasures we carried away. Before hoisting sail we saluted our discovery with a general hurrah, to bid it a last good-bye. The echoes of these silent regions, for the first time disturbed by human voices, repeated our cries and then returned to their habitual silence, so gloomy and so imposing; favoured by a good easterly breeze, we took our course to the ships, which were bearing off from land, often disappearing in their tacks behind the great ice-islands. We reached them only at 11 p.m. The cold was then extremely sharp. The thermometer registered 5° below zero. The outsides of our boats, as well as the oars, were covered with a coating of ice. We were glad to get back on board the corvettes, happy to have thus completed our discovery without accident, for in this glacial and capricious climate it is not good to leave one's ship for long at a time. The least wind overtaking

a ship on such a coast would force it to go out to sea at once and abandon its boats."

After this excursion, which left no more doubt as to the reality of our discovery, it remained only for me to extend the examination of it as far as possible. The weather seemed to lend itself favourably to this difficult course. The wind was east and blew us slowly westwards. Up to that time, and while any doubt remained, I did not wish to give any name to our discovery; but on the return of our boats I gave it the name of Adélie Land. The very projecting cape which we had seen in the morning when we were trying to get near the land, received the name of Cape Découverte. The point near to which our boats landed, and where they collected the geological specimens, was named Point Geology.

CHAPTER LX.

Examination of Adélie Land.—Navigation along the ice-pack.—Examination of Clarie Coast.—Return of the corvettes to Hobart Town.

1840. *Jan.* 22.—The nights had become so short that we hardly lost sight of the land after sunset. At 1 a.m. we could again see every detail. The breeze was so light that we had hardly moved. However, towards nine o'clock we had arrived off a vast, and quite open, bay. There the ice-crust which covered the land seemed furrowed in every direction by deep ravines, which caused me to name it the Bay of Ravines. We had already noticed a similar phenomenon before reaching Cape Pépin, but at the head of the bay the ice which covered the ground appeared so tossed about, that one would have said it had been thrown on to the ground in enormous blocks, as is often seen in recent volcanic regions. A multitude of floating islands of colossal dimensions were moving into the open. Their sides were formed of upright walls, but the upper surface, instead of being level, seemed also covered with pieces of ice, the crystal prisms of which crossed each other in every direction. This chain of scattered ice-islands produced a most singular effect. They probably rested on the bottom, perhaps even on separate islets, which served them for a base. Several times the man on the look-out thought he could distinguish dark spots among them; but it often happens that ice takes on a dark colour according as the light strikes it, and the indications of land which were reported were never sufficiently decided to establish for certain the hypothesis I have just thrown out. Several times we noticed also reddish tints in the floating ice without being able to guess the cause. Even on our course we met a small iceberg (*glaçon*) which showed this strange hue in a very

marked degree. For an instant I hoped to collect specimens of it, but we were still too far off to lower a boat to go for them; the wind dropped, and our corvettes were caught by currents and borne away far to the west.

Also among the floating icebergs we had noticed several with a brown colour, as if they had been soiled by contact with the earth. It is probable that these singular effects cannot always be referred to freaks of light, which vary to an infinite degree among these gigantic masses with their manifold forms. All these ice-islands are probably produced near the shore, and afterwards, on becoming detached, carry away with them débris attesting their origin. There was one of these extraordinary blocks a little distance in front of us, and I was most anxious to approach it; but the breeze did not spring up till after sunset. It was midnight when we passed it, coming quite close up to it. It had then the look of earth; but it was impossible to recognise the cause of this particular colour.

Jan. 23.—At 4 a.m. the watch reported that the sea was blocked in front of us by a chain of ice-islands. The sky was magnificent. There was no indication yet of any change in the weather. The breeze was light and regular, the sea absolutely calm. Being desirous of prolonging my examination of the land as far as possible, I wished at first to try and continue my course between the land and the chain of islands which had been reported to me; but as we approached, the man on the lookout sighted fresh ice-islands which were soon seen to be linked together by a continuous pack. This ice barrier, resting on the land to the south, stretched northwards, and then round to the east; we came very close to it; it was similar to those we had met in our first circumpolar expedition. Large icebergs surmounted it on all sides. The sea broke against it with force without shaking it.

Although my plans were thus unexpectedly upset, I hoped that the pack would not stretch far to the north, and that we could thus soon double it, and by sailing along it keep our course westwards. For a moment I thought that the ice-pack, ending about the 66th parallel, would leave us a free passage towards the west. There, however, it formed a great gulf, and in the centre nothing was to be seen but a line of floating islands, among which it would have been easy to pass; but in running north we again saw the ice-pack, which drove us east by barring our course. The weather continued magnificent. This field of ice, seen from the rigging, glittered under the oblique rays of the sun with a brilliancy like that of diamonds. In the midst we perceived an enormous mountain of ice, which so far surpassed in diameter those we had seen before, that we supposed there must be a nucleus of land to serve as its base. The wind being always east, we had to tack in order to emerge from the *cul-de-sac* in which we were caught. All day we remained in sight of this ice mountain, but nothing occurred to confirm our speculations regarding it.

Ever since our first circumpolar expedition we had constantly remarked that in the evening, after sundown, there is a fairly well-marked clearness above the icebergs, arising doubtless from the reflection of the ice. This clearness had always been a signal to us of the approach of ice-fields. Reduced to tacking at night in the middle of a space strewn with a large number of floating islands, we were obliged to redouble our care in order to avoid running against them unawares. We all knew well that our position might become dangerous if the east wind, which was preventing us from getting out of the gulf in which we found ourselves, were to blow strongly. Therefore that evening I anxiously surveyed all points of the horizon, and very quickly realised that we were still far from having reached the eastern extremity of the ice-pack, the direction of which I could study by the great clearness which it reflected in the sky. At 8 p.m. we stood in towards the land in order to make a long tack during the few hours of night which remained. At midnight the breeze seemed to increase. The swell which made itself felt from the east would have been a certain sign of bad weather, even if the sky had not become cloudy and very threatening.

Jan. 24.—At 4 a.m. we were running north, and I thought then we had doubled the ice-pack as we had spied a headland to the east the night before; but the man on watch soon announced again solid ice in front of us. The pack stretched north-east as far as we could see, thus extending the gulf in which we were confined. I instantly began to haul the wind, but realising soon that we could not double the ice (*glaces*) by tacking we went about to run once more for the land. Meanwhile the breeze freshened suddenly; the sea got up and for a few moments our position was most critical. Happily the space in which we had to run was not too much encumbered with floating ice. Only about twenty bergs were in sight; blown by the wind, they were visibly drifting towards the pack. Towards 1 a.m. the wind was coming in squalls of extraordinary force. Snow fell in whirlwinds and hid the land from us. Our horizon was limited to no more than three cables' length and navigation was most dangerous, for if we had at that moment met one of the huge icebergs which were so numerous, on our course, we might not perhaps have seen it in time to avoid it, and then what an end would have been ours! Our corvettes could not have borne the shock of these enormous masses of compact ice, and they would probably have sunk on the spot.

At the beginning of the storm the *Zélée* was only a few cables' length behind us. I hastened to signal to the captain that he should steer as he thought best for the safety of his own vessel, without troubling to remain any longer in our wake; but at that moment our ships were suddenly enveloped in a thick whirlwind of snow which prevented the signal from being seen. However, from that moment our corvettes lost sight of each other, and great fears soon seized us concerning the fate of

the *Zélée*. Notwithstanding the violence of the wind, we were obliged to carry as much sail as possible to prevent being driven on to the pack, where we should have been quickly and inevitably lost. Being forced, however, to clew up the mainsail in a squall, it was almost immediately torn to ribbons. Soon we had to take in the foresail; but we managed with great difficulty to set the close-reefed main topsail; the masts bent even under this reduced sail. Every moment we feared the main-mast would go or our topsails would be carried away and torn to pieces by the wind. The *Astrolabe*, floundering in the midst of waves which came over her on all sides, presented a terrifying spectacle; she heeled over to such an extent that her leeward battery was almost entirely covered by the sea. If at that moment and at the speed at which we were going, she had run against any obstacle, she would have been engulfed immediately. The cold was intense, and the fore part of the ship was hidden under a thick coating of rime. The snow, which fell thickly, caught on every rope and froze there, thus increasing its stiffness. The efforts of all the crew were necessary to execute the slightest order, and I was afraid that their strength would soon be exhausted.

Everyone, officers and men, did their duty admirably; notwithstanding all our efforts, however, I soon saw that far from gaining eastwards we were drifting rapidly to the west. Twice already we had tacked close to the pack, and each time I had noticed that notwithstanding our tacking we had been carried a long way to the westward. To crown our misfortunes, the compass had become quite inaccurate, just when precise indications were so necessary to us. As a matter of fact, while we had been running south, hardly altering our course, we had scarcely noticed the considerable deviation which the magnetic needle had undergone in approaching the magnetic pole. But on this day, the most terrible of all that we passed in the glacial regions, we had to sail in very different and often totally opposite directions; from that time all our compasses were untrue; we were so near the magnetic pole, that the horizontal force which directed our needles became too weak in comparison with outside influences; the indications of the compass immediately became faulty and irregular. M. Dumoulin, who spent much time in studying the anomalies of the magnetic needle, had, during the storm, collected together all the compasses we had on board into the quietest part of the vessel. Nevertheless, it was not for some days, after having made observations of comparative declination (variation) with the ship heading in all directions, that we knew exactly the route we had followed in the ice, and all the dangers that we had run.

On the 24th the floating icebergs (*glaces*) we had noticed before served as our sole guides; they sufficed to prove that, notwithstanding our tacking, the wind was carrying us rapidly to the westward, and our only hope of safety lay in a speedy diminution in the strength of the

wind. At 7 p.m. it had become so violent that all navigation was very difficult. It was impossible to remain in the rigging, which was covered with sharp icicles; the men could hardly stand on the deck, which was constantly swept by waves. It was an awful night; happily we only met on our course a few scattered icebergs, which we were able to see in time to avoid. No obstacle presented itself, while the snow falling in huge flakes, and a thick fog, hardly allowed us to see objects at the distance of one mast from another; for, as I said before, if we had met a single iceberg in such a situation, we should infallibly have been lost.

How painful were my reflections at such a moment! If we had perished that day, all the records of the expedition would have been destroyed; I had not even the consolation of thinking that I had been led into this new ice expedition by the instructions which had been entrusted to me. For myself, life was nothing: condemned to constant suffering, death would be almost a deliverance; but how different was the position of the young sailors with a most honourable future before them, who several days before had been so joyous and hopeful at the sight of the land we had just discovered. How eagerly I scanned the horizon! Uncertain of our position, I feared every moment to hear the terrible cry of "Ice-pack to leeward!" for I could not disguise from myself that, notwithstanding all our efforts, we should end by running on to those terrible reefs of ice without any chance of salvation. From the calculations of M. Dumoulin, only ten leagues separated us from the head of the gulf. Allowing for drifting, we should cross this space in twelve hours; but as we had to go about every instant in order to double the floating ice on our route, our chances of safety tended to diminish still more. It is in such danger as this that one can best judge of the crew who have to brave it. I can say that never did the men of the *Astrolabe* show a more noble courage; everyone, officers and men, on this occasion showed an intrepid zeal, a stoical abnegation, worthy of the highest praise. Two officers were constantly on duty on the poop; the men relieved each other hour by hour, but the cold was so intense, and the work so trying, that the crew were exhausted.

Jan. 25.—At last, the next day, at 10 a.m., the wind suddenly lowered, the gusts became rarer and less violent, the horizon cleared, and hope began to revive on board the *Astrolabe*. The man on watch thought he could see from aloft the *Zélée* a long way off to leeward, but the cannon which we discharged to show her our position received no answer. The wind soon began again to blow strongly, bringing with it snow, which blocked out the horizon afresh; it was the last dying effort of the storm, the wind sank all at once and became practicable; the horizon cleared, we saw land, and were able to note the effect of a gale upon the ice. All the islands which we had seen

on the 23rd in the middle of the basin where we had just run such great danger, had almost entirely disappeared; the ice-pack itself seemed to have receded under the violence of the wind. The observations which were taken later on one of the largest icebergs showed us that in truth the northern part of the pack had moved nearly three miles to the west. It was even possible that the iceberg which served us as a point of observation had been forced back westwards, and thus the entire pack could have shared in this motion without our being able to discover it. As soon as the calm returned, each of us, uneasy as to the fate of the *Zélée*, hastened to search the horizon, but in vain. Her position caused me grave fears: in spite of the fury of the squalls, in spite of the thickness of the snow, she had kept up in our wake at three or four cables' length; but when I signalled to her freedom of action, I had been told that she was clewing up her main topsail. Now, in such a position, damage alone could have compelled Captain Jacquinot to lessen sail; I had, therefore, every reason to fear that the corvette, not being able to carry her canvas, had drifted rapidly on to the iceberg, where she would certainly have foundered; and in that case it would be indeed fortunate if, even at the risk of disaster to ourselves, we could have rescued our unfortunate comrades from so terrible a shipwreck. During the evening the fears which tormented us concerning the fate of our consort were slightly allayed: after five o'clock the man on watch thought he caught a glimpse of her six or seven miles to leeward. It was not till six o'clock, as we were making a long tack towards the land, that we suddenly recognised quite clearly our faithful companion, with all sail set in order to reach us. She had fallen about seven or eight miles to leeward, had seen us and crowded on canvas to beat up to us. At once I bore down gently upon her, and two hours later the two corvettes were sailing quietly side by side, as though nothing had happened. At this moment my heart was relieved of a great weight, for all the satisfaction I had felt in the discovery of Adélie Land would have been poisoned for me by the loss of the *Zélée*, if such a catastrophe should have ended her career, or even if it had been necessary to abandon her in these gloomy latitudes. In the evening the sea became once more very beautiful; a gentle south-west breeze rose, and a hope sprang up in my mind of being able to sail along the coast eastwards, after having been so abruptly stopped to the west.

Jan. 26.—The whole of the 26th was therefore spent in beating up to the land, from which we were at night only three or four leagues distant; we were obliged at the same time to repair the damage caused by the last gale. I had not been able to communicate with the *Zélée*, but it was evident that she had suffered considerable damage to her sails during the bad weather, for her crew were employed all day in bending new sails to the yards.

In the evening we succeeded in beating up to a long line of scattered ice-islands, which had only very narrow channels between them. We imagined that the blocks of ice were the same as those among which it had been necessary to pick our way, when, on the 20th, we had tried to approach the land. We counted more than 150 ice-islands round us, among which several persons thought they could recognise some of those which we had already seen on the 20th. I have said already that all these islands had nearly the same appearance, and even though I did not think it was possible to recognise them by their particular form, I am, nevertheless, convinced that all these blocks of ice were the same as those in the midst of which we had steered our way on the 20th. However that may be, the wind, which abated in the night, shifting to the south and then to south-east, forced us soon to change our direction. I did not hesitate for a moment to run our corvettes into the middle of this chain of floating bergs, in order to escape as quickly as possible from the gulf where we had just been in such danger.

Jan. 27.—During the night we again found ourselves surrounded by huge walls of ice which bound the floating islands, and the appearance of which, at such close quarters, had already seemed to us so imposing. It happened several times again that we found ourselves so much shut in between these threatening walls, that it was to be feared that at any moment our corvettes might be drawn into the eddy formed by the waves breaking round them. The night looked threatening. The sky gradually clouded over again, and we were able to congratulate ourselves on having passed this chain of floating islands when daylight brought us strong east winds and much snow. I gave the order to direct our course northwards; at any price we must get away from the land; snow fell abundantly, and once more our course was fraught with the greatest danger. We redoubled our care and watchfulness in looking out for the icebergs, which at any moment might bar our passage, but the fog was so thick that in all probability we should not have had time to avoid them. At midday the man on watch signalled the ice-pack; we had not had time to alter our course and bring her up to the wind, before we were right in the middle of it. Happily it was a false alarm; the icebergs (*glaçons*), which had appeared to form a field of solid ice, were nothing but débris, through which it was easy to pass. It is probable, however, that they came from an ice-pack not far off, of which a part had been detached by the violence of the wind. However that may be, we were able to extricate ourselves easily, and as the wind was then blowing very strongly we hove-to, the head of the ship being set northwards. All day snow fell incessantly. We saw several floating islands; but by the evening we found ourselves quite free.

Jan. 28.—During the 28th the wind went round again to the west. The sky cleared perceptibly, and at midday we could take our latitude; I turned our head southwards, hoping we could continue our exploration

of Adélie Land, but in the evening an east wind blew again. Snow began to fall abundantly. The sea was beaten up, and became rough.*

Jan. 29.—The next day, the wind being apparently steady in the east, I thought I ought to give up all attempts to penetrate further in this direction, and I then began to consider how to direct my course in the best possible way towards the discovery of the magnetic pole. After consulting M. Dumoulin, the order was given to sail south-west, in order that we might cross all the magnetic meridians whose curves seem to approach most nearly those of the terrestrial meridians. At midday we were about 64° 48′ S. latitude: only two or three ice-islands were in sight. The sea was still running very high, but the weather was fine though foggy, and our corvettes under full sail, having the wind astern, moved rapidly. At 4 o'clock the man on watch signalled an iceberg (*glace*) of immense extent in front of us and not far off. Indeed, we soon saw through the fog a long line of ice, stretching from south-east to north-west, and apparently continuous. Accordingly I gave the order to bring her closer to the wind. This had hardly been done, and the officer of the watch was about to give the order to board the main tack, which had meantime been clewed up for the moment, when the man on the watch signalled a ship running towards us before the wind. Immediately everyone was on the poop. We were all in fact very glad to assure ourselves of the truth of news so unexpected in such latitudes. The ship was moving quickly, and it was already very near us when the man on watch had announced it. Till that moment it had been hidden by the fog. The same moment as we distinguished her form, we could recognise the flag she had at once run up on seeing us. It was an American brig, and the national pennant which floated at her mainmast showed that she was a man-o'-war. As I have already said, we knew when we left Hobart Town that the American expedition, which was composed of several ships under command of Captain Wilkes,† and destined for a voyage of circumnavigation, was at Sydney in December making preparations for a new polar expedition. Therefore, we were certain that the brig we saw belonged to this expedition; and she, on seeing our corvettes, had perhaps hoped we were part of the American expedition. However that may be, although we had hoisted our colours the ship continued to come towards us, and I hoped that she intended to speak us. In order to help her, I gave the order to wait a few moments before boarding the tack.

* This continual east wind in high latitudes is very remarkable. It is well known that, between the 30th and 68th parallels, the prevailing wind is almost constantly from the west. It is not impossible that beyond this limit the east wind becomes more frequent than the west. We do not yet know anything of the meteorological observations made in the same latitudes by Captains Wilkes and James Ross; but the routes followed by these navigators in their exploration of the polar regions seem as if they should lead to the same conclusions.—V.D.

† Compare Wilkes' account of this meeting, page 415.—Ed.

The American brig was soon no more than a cable's length behind us, and I thought her captain intended to pass to port of the *Astrolabe*, and to remain a short distance to leeward. Now, since the ship under full sail had maintained a great speed compared with our own, and would rapidly have passed us, if at that moment she had gone to windward, I gave the order to board the main tack in order that the *Astrolabe* might remain longer alongside. This manœuvre was probably misunderstood by the Americans, for the brig instantly bore off to the south, and went away quickly. Afterwards, the reports of Captain Wilkes which reached me, in mentioning this meeting, attributed intentions to me which were very far from my thoughts. Certainly, if I had not wished to communicate just then with the ship which had signalled to me, I should not have delayed so long the boarding the tack, to keep off a little from the ice-barrier we had met, as the fog had prevented us from seeing the way. We had no object in keeping secret the result of our operations, and the discoveries for which we had nearly paid so heavily. Besides, these are no longer the days when navigators, impelled by the interests of commerce, think themselves obliged to hide carefully their route and their discoveries in order to avoid the concurrence of rival nations. On the contrary, I should have been glad to give to our co-explorers the result of our researches, in the hope that it would have been useful to them, and enlarge the circle of our geographical knowledge. If I can believe what was told me in Hobart Town, it seems that the Americans were far from sharing these feelings. They have always maintained the greatest secrecy concerning their operations at all the points where they landed, and they have refrained from giving the slightest indication of the work which they accomplished.

Jan. 30.—The snow, which had fallen ceaselessly and heavily the evening before, stopped during the night. The morning of the 30th opened under brighter auspices. The wind was still in the east, and the sea rough, with a swell; but the horizon had become much clearer; at 6 o'clock the man on the look-out had sighted the ice-pack to the south, and I brought the ship to the wind in order to go nearer to explore it; at 10 o'clock we were not more than three or four miles distant. It appeared prodigious. We saw a cliff with a uniform height of 100 to 150 feet, forming a long line westwards. At several points narrow slits seemed to separate ice-islands from the great mass; if these slits extended sufficiently far down to entirely isolate the icebergs (*glaces*) we saw, they were larger than anything we had ever seen among floating ice. From afar, we saw very well-marked capes and indentations; but all these irregularities were always terminated towards the sea by a straight vertical wall, covered at its base by smaller pieces of ice (*glaçons*). These fragments, resulting from the continual beating of the sea on these masses of ice, prove how little effect the waves have on this

obstacle; for notwithstanding their force they had only been able, with their incessant hammering, to tear off a few small pieces.

We spent all day sailing twenty to twenty-five leagues along this ice-coast without seeing any peak rising above the snow plain. The cliffs along the shore were too high to allow us to distinguish the details of the interior. In vain we scanned carefully all the contours, trying to discover some rock or sign of land; everywhere we beheld nothing but compact ice, reflecting in a thousand different ways the luminous rays which fell on it.

In the evening we reached a projecting headland on this extraordinary coast. Here its direction seemed to change, appearing to go off to the south-west, and the clearness we had noticed in this direction after sunset, showed that it stretched away to the west for a very long distance. At this point we finished our exploration. At 6 p.m., before taking our course to the west, our ships seized a moment of shelter under the ice to communicate with one another. While a boat from the *Astrolabe* went off to the *Zélée*, we let down a sounding-line of 200 fathoms, without finding bottom. A thermometer was fastened to the lead, and registered at this depth one degree less than on the surface. M. Dumoulin expected to have found an increase rather than a fall in temperature, the water at the surface being at zero. He attributed this result to the fact of our being too near to the ice (*glaces*). For my part, I willingly accept his view—namely, that when the water at the surface is at zero, one would expect to find an increase of temperature in soundings of great depth.

Thus, for more than 12 hours we had sailed along this ice-wall, which was perfectly vertical at the edge and horizontal at the top. Not the smallest irregularity, not the slightest eminence, broke this uniformity in the course of the 20 leagues which were made that day, although we sometimes sailed at a distance of two or three miles out, in order to note the slightest irregularities. Several large icebergs (*glaces*) lay along the icy coast, but in general the sea was almost free in the open.

As to the nature of this enormous wall, opinions were once more divided, as when we had sighted Adélie Land; some holding that this was a mass of compact ice independent of all land, and others, of which I am one, maintained that this formidable belt was at least an envelope, a crust, covering a solid base, either of land, of rock, or even of scattered shoals round a vast land. This view I base on the principle that no ice of great extent can be formed in the open sea, and that it must always have a solid point of support to allow of it being formed while stationary. Thus, in the Arctic polar regions one sees in winter great stretches of coast entirely buried under thick layers of ice. Even in the northern parts of France one sees after heavy falls of snow followed by sharp frost the inequalities of the soil become gradually obliterated, and often

completely hidden under the layers of snow which cover them. On this hypothesis, however, I acknowledge that it is difficult to explain the perfect uniformity of the ice-layers which formed our great wall; I am reluctant to admit that such gigantic masses are the product of a single year, and if not, one ought to distinguish the deposition of successive years by layers more or less horizontally inclined. However this may be, at 10 p.m. I gave the order to sail south-west, after having bestowed the name of Clarie Coast on the barrier of ice we had just been exploring.

Jan. 31.—The next day, the 31st, I expected to find once more our ice-wall, but at 3 a.m., although I had gone to the south during the night, we saw in its place only a formidable chain of floating islands. We noticed at the same time, in the south-west, that well-marked clearness which appears at twilight above ice-fields. Soon after, indeed, we saw in this direction an ice-pack which stretched to the west and north-west, as far as the eye could see, seeming to form a great gulf round us. This pack resembled all those we had already seen. It was flanked by immense ice-islands, bound together by a layer of small blocks of ice (*glaçons*), less thick, but yet offering an insurmountable obstacle to our ships. We had then reached 128° long. The variation, from being north-east, had become north-west and very marked. Thus, during those tempestuous days, we had passed the meridian where the declination is nought. MM. Dumoulin and Coupvent believed they had gathered sufficient data to determine the position of the south magnetic pole. Nevertheless they still wished to observe the declination with the ship heading in every direction, and once more to take magnetic observations on a floating iceberg (*glaçon*). Consequently I spent all day looking for a suitable iceberg on which to land these officers. At midday I thought I had succeeded. I sighted an ice-island horizontally inclined, on which it seemed possible to land; the whale-boat was lowered, but on approaching it our men realised the impossibility of climbing up it. The sea broke against it with force, and the spray rose more than five metres high. Also, the horizontal part was formed of a layer of extremely smooth and slippery ice.

Feb. 1.—The next day opened under conditions which were more favourable to our operations. It was almost a calm, and the swell was very gentle for these latitudes, which are constantly lashed by storms. Several ice-islands were in sight, and seemed to our physicists to offer better opportunities than those of the evening before. One of them especially showed a vast plateau, but slightly raised above the level of the sea. At 8 a.m. the whale boat, with the physical instruments on board, attempted to come up alongside of it to leeward, while the corvettes made short tacks in order not to drift away. For a moment I hoped to have attained the object I had been pursuing for the last two days, but soon I saw the boat, having made the circuit of the first ice

island, make for a second, which was smaller and consequently much less steady. MM. Dumoulin and Coupvent soon returned on board, and reported to me that the base of the first iceberg (*glace*) they had visited was incessantly washed by the waves, which, after breaking in the caverns they had hollowed out of the mountains, fell back with a crash into the sea, thus forming large cascades, of which we saw nothing from the ship. As to the second iceberg (*glaçon*) to which they had gone, it was so shaken by the swell that it would have been impossible to make any observation on it, and indeed the boat would infallibly have been capsized if she had gone alongside.

I then had once more to give up hope of making the magnetic observations which presented so many difficulties. I devoted the rest of the day to turning the ship round on herself in all directions, while simultaneous observations of declination were made fore and aft. This operation, which I should like to have repeated later, was then quite easy, for the azimuth of any one of the ice-islands in sight could be determined at any moment. The results were very strange, showing differences of nearly 12 degrees in the various declinations obtained under opposite heads (*caps*). I still kept a look-out all day for an iceberg on our course which would allow of another attempt at landing; but in vain.

I considered then that our task was fulfilled. The *Astrolabe* and the *Zélée* could retire from the arena, having furnished for their part a considerable quota to geography and physics. Of course it would not have been impossible to push on further west, and trace out a greater extent of the ice-pack, or perhaps even find land again. For I believe that the greater part of the polar circle is surrounded by land, and that in the end it will be found by some navigator sufficiently fortunate and bold to break through the masses of accumulated ice which ordinarily surround it; unless, indeed, some obstinate and insurmountable ice-pack should frustrate his efforts; but I considered the condition of the crews, especially that of the *Zélée*, which was much more serious than that of the *Astrolabe*. I felt it would be cruel to abuse their courage, and the confidence they had shown in following me thus far without a murmur. I reflected that any important work and a long voyage would make demands on their strength and bravery for at least eight months; finally, I may as well confess, I was myself very tired of the rough time I had been going through, and I much doubt if I could have borne it much longer.

During this short, but hard and perilous voyage, all the officers and men of the two corvettes had, without exception, done their duty perfectly, and I had nothing but praise for their conduct. In the evening of February 1, 1840, in S. lat. 65° 20′ and E. long. 180° 21′, we bade a final adieu to these wild regions, and I set the ships' heads north to make Hobart Town.*

* I have taken a great part of this chapter from the report addressed by M. D'Urville to the Minister of Marine, dated Feb. 19, 1840. The journal kept by the chief of the

I had determined to put in there a second time, in order to procure a few days' rest and refreshment for our men before leading them on to fresh effort. Certainly they had well deserved this small treat, for it would have been impossible to show more courage, resignation, and even self-sacrifice and scorn of death, than they had exhibited at the most critical moments. Besides, this determination could in no way upset my plans for the future, for it was necessary in any case for one of the corvettes to go to Hobart Town to take up our sick, while the other would have to wait for her at one of the ports of New Zealand.

For several days winds from east and north-east continued to thwart us by blowing very unsteadily and raising high seas, which tried us cruelly.

Feb. 4.—On February 4th a thick fog enveloped us; however near we kept to each other, it was impossible to distinguish the *Zélée*. The sound of the bell and frequent cannon shots helped us to prevent drifting apart.

Feb. 6.—On the 6th we had reached the 58th parallel. Till then we had always seen several floating ice-islands of strange form, showing plainly that they had been a long time in the sea, where they were with difficulty resisting the action of the waves. That morning we still saw three or four, but after that they became more and more rare. At the same time the wind, which had blown pretty steadily from the south-east, suddenly fell.

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expedition during this time consists as usual of a narrative of the principal facts which came under his eyes, without mentioning the services specially performed by each officer. If M. D'Urville had been able to write out this part of his work, he would have mentioned in detail these services in their order and place. I feel it therefore my duty to reproduce here the portion of M. D'Urville's report in which he expresses to the Minister of Marine his satisfaction with the behaviour and zeal of his staff. The paragraph runs thus:

"I must here make particular mention of the names of those men who, staunch to their orders, have never ceased to show me the most absolute devotion, and the most honourable confidence, combined with the most enduring enthusiasm for the glorious work they were called to share. Their loyal co-operation and the certainty of earning at least their approbation have alone enabled me to rise above many disappointments, to persevere in my plans, and finally to take upon myself the terrible chances of my last effort towards the pole."

Then follows the list of officers for whom he asked rewards. Finally the report, which can be found in entirety among the justificatory extracts contained in the 10th volume, ends as follows:

"I have considered myself justified, Sir, in promising to the crews, after our last efforts and success, and above all on account of their excellent conduct, that the prize-money promised them would be paid. I feel persuaded that you will acquit me of my promise. I am even persuaded that if a legislative measure were necessary you would not hesitate to propose it to the Chambers, who would doubtless pass it eagerly. Who knows even if the Chambers, astonished at the moderation of the amount, might not propose to raise it to a sum more worthy of a great nation? Indeed, what is it to a government like that of France, to divide a miserable sum of 12,000 to 15,000 francs among 130 men, as remuneration for so much fatigue, privation and misery?" (This prize-money has been awarded.)—V. D.

Feb. 7.—The next day the weather was cloudy; soon we felt a slight gust from the north-west, and a fine rain fell, mingled with snow, which melted on reaching the deck.

At 9 p.m. we were all summoned to the deck by one of those magnificent sights so common in high northern latitudes: I allude to the aurora, the luminous rays of which suddenly light up the sky during the long winter nights. In the evening the sky had cleared, but all the horizon had remained enveloped in a band of fog, which hid all stars except those near the zenith. Shortly afterwards the east wind, which had been blowing strongly all day, bringing up much rain, suddenly dropped, and at the same time the sky was lighted up by a new light like that of the moon, and variable in intensity. Pencil rays, broad below, thinning off above, seemed to converge to the same point, about five or six degrees north of our zenith. All these rays, developed *en tiroir*, one above the other, seemed to preserve a great mobility; their base did not rest on the horizon, and the bank of fog I have mentioned prevented us also from following them down to the level of the sea. At 10 p.m. these luminous rays formed a perfectly spherical cap; at this moment the spectacle was at its best, but this did not last long, and the rays were only partially visible, embracing a more or less broad space, but never again forming a complete cap. It was above all in the south-east and north-west that it was most brilliant. We noticed no sudden variation in the needles of our compasses. M. Dumoulin tried in vain to make some magnetic experiments. The sea was very rough; the ship, not being steadied by the wind, kept turning about, and the rolling did not allow any observations to be made.

Feb. 9.—During the two following nights part of the sky was lighted by similar auroras, but the phenomenon was never so striking as on the night of the 7th. Afterwards the wind veered to W.N.W., and we saw no more of it.

On the 17th we reached the entrance of the Bay of Tempests, and that day we again dropped anchor in the roads of Hobart Town. We had already enquired of the pilot concerning the condition of the sick men we had left on land; he said he had heard that several of them were dead, but he could give us no further details, which made us very anxious. We were, therefore, impatient to see one of our own men, to learn positively how many more victims we had to deplore. However, soon, M. Hombron, who had recognised our ships, hastened on board; he informed me that during our absence three men had succumbed. The *Astrolabe* had to mourn one named Bernard, a young and interesting sailor, of gentle and polite manners, in the highest degree zealous and devoted. I was not unprepared for this loss, for at the moment of our departure this unfortunate man had been seized by dropsy supervening on dysentry, and was almost beyond hope. More unfortunate still, the *Zélée* had lost a good sailor named Beaudoin, and her master carpenter,

Coutelenq. "We had left the latter," says M. Dubouzet, "in an almost desperate condition. But his death was a great grief to me. He was an excellent servant, and a very clever man in his profession. I esteemed him highly; I had already sailed with him before, and he had given proof of a consummate skill under difficult circumstances. I had always considered him capable of building us a ship in the event of our being cast on one of the isolated islands of Oceania. In a word, he combined all the qualities necessary for such a voyage as ours. Beaudoin was the last of the three volunteers from the *Ariane*, who had embarked on board the *Zélée* at Valparaiso; all three had succumbed, one after the other, during the voyage, which they had entered upon of their own free will."

All the others were convalescent, and ready, added M. Hombron, to go to sea. M. Demas had quite recovered. For several days he had been able to take exercise on the promenade, and at the actual moment of our arrival he had gone to visit Port Arthur. But unfortunately the *Zélée* had returned to Hobart Town bringing two men whose lives were in serious danger, and in all probability the unfortunate men would never recover their health.

M. Hombron informed me also that during our absence the roadstead of Hobart Town had been often visited by French whalers. Eleven and twelve had been counted at one time at anchor in the harbour, and among the ships round us we could then count three flying our colours.

EXPLORATION OF ANTARCTIC LANDS.*

By HENRYK ARÇTOWSKI.

ON Friday, January 14, 1898, the *Belgica* left St. John harbour in the morning, and obtained a sounding near the shore giving a depth of 162 fathoms; a second sounding later in the day gave a depth of 855 fathoms. Next day we lost sight of Staten island, and obtained a sounding of 2209 fathoms. This was our first discovery—an unknown depression lying close to the extremity of the Andes, the steep slope of the mountains being evidently continued under the sea. The prolongation of the great mountain chain is to be looked for to the east of Staten island, which forms the last fragment of the Andes; but in that case, what can we make of the Diego Ramirez islands south-west of Cape Horn? The latitude at which we had found the deep sounding was within a few minutes of that of the Cape, the exact position being 55° 51′ S. and 63° 19′ W. One is led to speculate as to whether the chain of the Andes does not open out like a fan, as so many other mountain chains do.†

On January 19, Commandant de Gerlache pointed out the ice-blink in the south. The sky was uniformly covered with a thin layer of stratus, and just at the horizon a white line appeared like a longitudinal slit, detaching itself by its brightness from the grey of the sky. It was discontinuous, a little undulated, not rising more than from 10′ to 25′ above the horizon. At 8 p.m. Lecointe reported the first iceberg, which appeared like a dome rising sharply out of the sea at a distance of about 10 miles. The soundings had given depths of 2105, 2078, and that morning 2018 fathoms; the depth was thus diminishing towards the south.

On the 20th we sounded in 62° 2′ S. with a depth of 1586 fathoms, and at 4 p.m. land was sighted on the horizon, and the depth in 62° 11′ S. was found to be 1028 fathoms. Thus the bed of the ocean was rising

* Personal narrative of the twenty landings on the lands discovered by the Belgian Antarctic Expedition.

† Arçtowski, 'The Bathymetrical Conditions of the Antarctic Regions' (*Geogr. Jour.*, July, 1899); and Arçtowski, 'Observations sur l'intérêt que présente l'exploration géologique des terres australes' (*Bull. Soc. Géol. de France*, 1895, p. 589).

fairly steeply when near shore. At 6 p.m. we were able to make out high mountains, the summits standing out black against the sky, and the gentler slopes covered with snow; these were the South Shetlands, discovered by Dirk Gerritsz in 1599, and re-discovered by William Smith in 1819. At 9 p.m. the profile of the land was so clearly visible that by means of a field-glass I was able to make a sketch of Livingstone island. Smith island, which was visible to the right of Livingstone island,

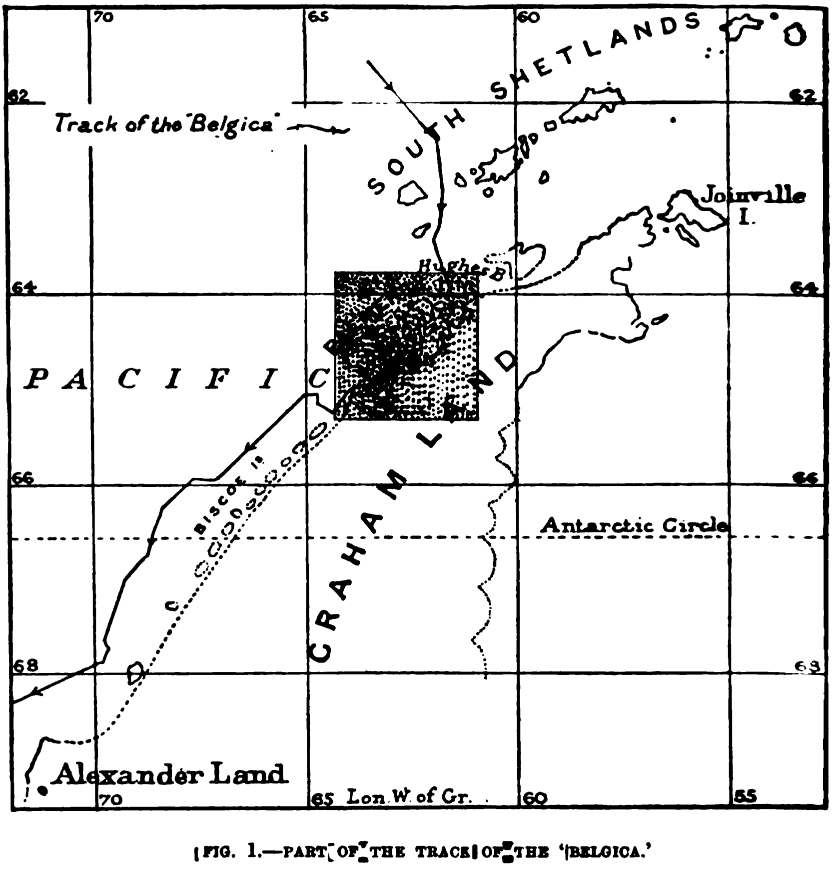


FIG. 1.—PART OF THE TRACK OF THE 'BELGICA.'

plunged almost perpendicularly to the sea; it appeared to be a rounded mass cut here and there into cliffs. We had to pass between these two islands. A large iceberg appeared in the south-south-east, and others lay off the islands; at eleven o'clock we passed some pieces of floating ice, and saw more towards the south, and then a little fog, accompanied by fine rain, shut out the view.

On Friday, January 21, while we were at breakfast, a little after

eight o'clock, we felt a sudden shock, which seemed to lift the ship twice; rushing on deck, we found that a thick fog made it impossible to see any distance, but on the starboad side there was a large mass of ice, here and there vague forms of icebergs loomed up ahead, and quite close to us we saw the rock on which the ship was fast. The fog lifting a little, let us see that we were surrounded by rocks. Some of the large blocks of ice were aground, others afloat. On deck no one spoke; nothing was to be heard, although the weather was calm, but the roar of the breakers on the rocks and the cracking of the ice. The engine went astern, and after a few moments we were afloat again. Splinters of wood torn from the keel rose to the surface, and helped us to realise the gravity of the danger we had escaped.

The splendid spectacle of the icebergs, however, made us forget all else. One of these was like a tower cut out of a great block of sugar; another, a mountainous island, with a bay in which the billows broke in foam; yet these were mere fragments of icebergs, broken and of fantastic outline.

At eleven o'clock more ice appeared, and also more rocks, which gave an anxious time to Lecointe, who was on watch. The fog lifted about noon, and for a few minutes we could see a low land covered with great fields of snow, which terminated in the sea as perpendicular cliffs of ice; this was probably Snow island. Other land could be seen further to the east, with summits bare of snow. Several large bare rocks rose abruptly in front.

On Saturday, January 22, the number of the ship's company was unhappily reduced to eighteen, poor Wiencke being carried overboard by a wave and drowned. It was terrible to be quite near a man who was fighting with death, and yet to be unable to help him. All our efforts were in vain; twice he was almost saved, but Fate willed otherwise.

Bad weather commenced at night; all day the wind had been blowing in heavy squalls, and the sea was rough. The fog continued, and in the afternoon snow began to fall. Since morning icebergs had always been in sight, looming up vaguely through the fog, or appearing in all their splendour during the short clear intervals. Many of them were tabular; complicated forms were less common, for they had come from no great distance, doubtless originating in the land which was in sight. The ship had at length to be laid-to, and, the gale increasing still further, it was necessary to seek the shelter of an island, which no doubt was Low island. At 6 p.m. the weather cleared, and allowed us to see the island, which is extensive and surrounded by large bare rocks, but itself completely covered with a thick mantle of ice and snow, which hides all irregularities under a uniform surface, and descends to the sea in perpendicular cliffs of ice. Bird-life was very abundant in the "rookeries" which we saw round the island, full of penguins, and

lending a strong odour of guano to the breeze. We resumed our way, and the island dropped out of sight.

On Sunday, January 23, the sky cleared at last, the clouds parted, the sun shone, and our radius of vision gradually extended. We were to the west of Low island, which we could now see much more clearly. It seemed to be low and entirely surrounded by huge rocks and abrupt islands quite free from snow. The air was poisoned by the smell of guano. M. de Gerlache changed the course to east-south-east, in order to enter Hughes gulf, and we passed again some icebergs seen on the previous night. One of these was particularly fine and characteristic, with a height of 130 feet and a length of 250 yards. I made two drawings of this berg from different sides. These represent it as a plateau bordered by cliffs and topped by a mound. On one side one could see that the summit was composed of thin layers of snow, perfectly parallel and horizontal. The colour of the ice at the base was a very pale greenish blue, but the blue was intense in a large hollow—a veritable azure grotto. Position at noon, 63° 28′ 30″ S., long. 62° 13′ W.

On leaving the island the floating ice was gradually left behind, the weather again became squally with fog and rain, and about 3 p.m. more ice appeared again; generally in a tabular form, but sometimes as isolated peaks or as tables dipping to one side, in which case the lines of stratification remained parallel to the surface of the berg. The weather gradually cleared, and land was sighted, at first a series of islands and rocks, and then a more extensive coast. At 7 p.m. we passed close to a headland, which very probably was Cape Cockburn, but as we went on the charts became valueless; what we saw corresponded to nothing that they represented, and Lecointe proceeded to take bearings at frequent intervals, which allowed him to construct an approximate chart. At 10 p.m. land seemed to block further advance towards the south; high mountains appeared on the horizon, and islets and rocks were scattered over the great bay at whose entrance we had arrived. Many places were clear of snow, and numerous peaks projected above the ice-sheet, so that it would be possible to study the geology. At 10.30 we were close to an island, and de Gerlache, Racovitza, Cook and I got into a boat and made our first landing in the Antarctic regions (see Fig. 2, I). A considerable part of the island was uncovered. The upper part was like a lava-flow of prismatic structure; lower down the rock was completely cracked, and seems to decompose in large superimposed blocks with straight surfaces. It is an eruptive rock of great density, very hard and brittle, and rings on a blow with the hammer, It is not basalt, but of granitic structure and very fine-grained; its colour is a very deep green, and I thought that I saw small crystals of hornblende—if so, the rock is a diorite. I had no time to examine the snow, as it grew dark, and we had to return on board.

Monday, January 24, was a day of discoveries, and it is impossible

to put down here all that I saw, or even everything which struck me as of special interest. During the night the *Belgica* had to be manœuvred to avoid icebergs, and to prevent being driven on shore by the wind. In the morning it was necessary also to go out of our way a little in order to recognise our bearings of the night before, and to find the islet on which we had made our first landing. In passing close to an island

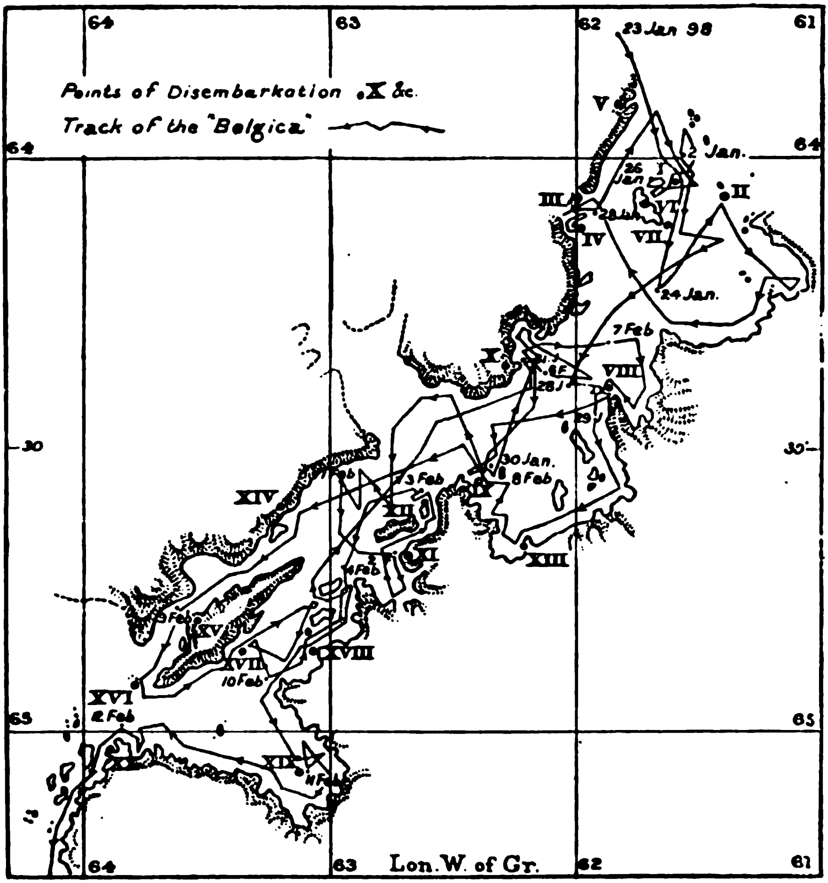


FIG. 2.—PART OF THE TRACK OF THE 'BELGICA,' SHOWING LANDINGS.

which was almost free from snow, Racovitza, Danco, Amundsen and I got a boat out and landed for the second time (II on map, Fig. 2). It was a small, narrow island, no more than 100 feet high, and appeared to be surrounded by a close colonnade on account of the regular vertical cracks in the rock, which were doubtless produced by extreme cold. The surface was frequently mammilated and worn smooth by the ice. A little sandy clay mixed with guano was found in small pockets

between the rocks, and while examining this clay I had the pleasure of discovering the first Antarctic insect, almost microscopic in its dimensions.

In the afternoon a breeze sprang up suddenly, and the sky gradually cleared; but the fog descended on us again with equal suddenness, just as it does on mountains above the cloud-level. Every now and again a momentary clearing revealed a beautiful picture of mountain peaks, the bases of which were covered, of great glaciers losing themselves in the clouds, or of fantastic icebergs, everything appearing larger than nature because there was no perspective, and the fine pictures themselves were vaguely framed in cloud. The light, however, was abundant, the low clouds which sometimes touched the sea were white and even brilliant, and sometimes a beam of sunlight threw a sparkling lustre on the ice, or on the great snow-fields, or on the sea.

The silence which brooded over this unknown world was singularly impressive, but occasionally a mountain of ice would collapse with a thundering crash. One could hardly believe one's eyes when these changes in the fairy-like scene occurred, were it not for the dull rumbling growl of the disrupted glaciers. In fact, this realm of eternal ice is so different from anything one had seen that it appeared another world altogether; in sober truth, I do not believe that in any fable the human imagination has described what we have seen there.

From the point of view of astronomical observations Lecointe has been unfortunate, as the sun had rarely shown itself, and he had only been able to fix the latitude (64° 9′ at noon). He kept up a continuous survey of the coast as we passed near the shore, and so succeeded in making a chart of Hughes gulf. The only maps which we possessed—and they are all that exist—were the British Admiralty chart, No. 1238, and Friederichsen's map. The general result of the day's work had been the discovery of an elevated land where Friederichsen's map bore the inscription, "No land in sight (Larsen)." Towards the east and south an uninterrupted coast-line stretched as far as the eye could reach, but in the south-west a large strait opened into the gulf, and this it was necessary to explore. The land in the north-west was also divided by a channel, towards which the commandant first directed the ship. The large bay which we had coasted during the afternoon was very free from ice, although as we went further into the bay the number of bergs increased, but still the *Belgica* had no difficulty in approaching close to the shore. At the head of the bay my attention was particularly drawn to the floating ice. Several of the numerous icebergs were of quite respectable dimensions; their form varied considerably, but usually more or less tabular; one of the bergs was pierced, forming a floating triumphal arch. The stratification of the ice was rarely noticed, but in diffused light it is not easy to make out the difference between the alternate layers of blue and white ice; still, in the upper part of the

walls the stratification of the *névé* was often seen. The blue colour of the hollows in the ice was more intense as the light was stronger. Each berg was surrounded by a wide horizontal groove formed by the waves at the level of the sea, and one could often see the grooves of former levels, which showed that the position of equilibrium had changed, and one little iceberg to which we were very close showed two such lines which crossed each other. The surface of the ice reflected so much light that Cook was able to take instantaneous photographs of the floating ice down to the moment of sunset, and even a little later; they were rather faint, it is true, but the outlines were quite clear. It was very difficult to judge distances, one piece of snow-covered land lying in front of another appearing to be part of it, and thus it was necessary to follow the coast very closely in order to distinguish islands from peninsulas.

The quantity of snow which has been accumulated in this region is really formidable. The westerly and northerly winds coming from the ocean doubtless bring great falls of snow, and this is always accumulating, mountains of ice being reared on the top of the mountains of rock. So far as I could judge from the ship, the ice was nowhere uncovered, but thick snow seemed to lie on the glaciers down to the very edge of the sea.

The sunset was very fine, and after it, about 9.30 p.m., the clouds were brilliantly coloured, and the south-western horizon became remarkably clear. At ten o'clock the ship was stopped quite close to the shore, at the entrance to the north-western passage, which doubtless led to the ocean. I was anxious to land to collect some geological specimens, but it was necessary to manœuvre the vessel all the time, in order to avoid shoals and floating ice, and, besides, the commandant did not see the use of landing here, so I had to give it up. About midnight, Lecointe, who was on duty, saw something floating which appeared exactly like a fragment of wood. This was a good opportunity for launching a boat, so Racovitza, Tollefsen and I set out to see what it was, and, after having found that it was only a piece of ice filled with pebbles and clay, we naturally rowed ashore and landed in a little bay (III on map, Fig. 2), where I had the good fortune to come upon a moraine, which I believe was a ground moraine. There was water behind the moraine, and then a cliff of ice, the end of a great glacier which covered the whole slope of the mountain. Although it was growing very dark and the specimens were collected hurriedly, we found more than ten different varieties of rocks, but none of sedimentary formation. The pebbles were, as a rule, perfectly round, and usually large, while there were also many big blocks.

Tuesday, January 25, was fine and calm, the air perfectly transparent, the sky cloudless, and the heat of the sun intense. We landed at 7 a.m. Lecointe and Dobrowolski, in order to make astronomical

observations, Danco for magnetic work, Racovitza to search for plants and animals, Cook to take photographs, and I to collect geological specimens. Amundsen went with us. We landed on the promontory of an island (IV on map, Fig. 2), and it was not without difficulty that all the

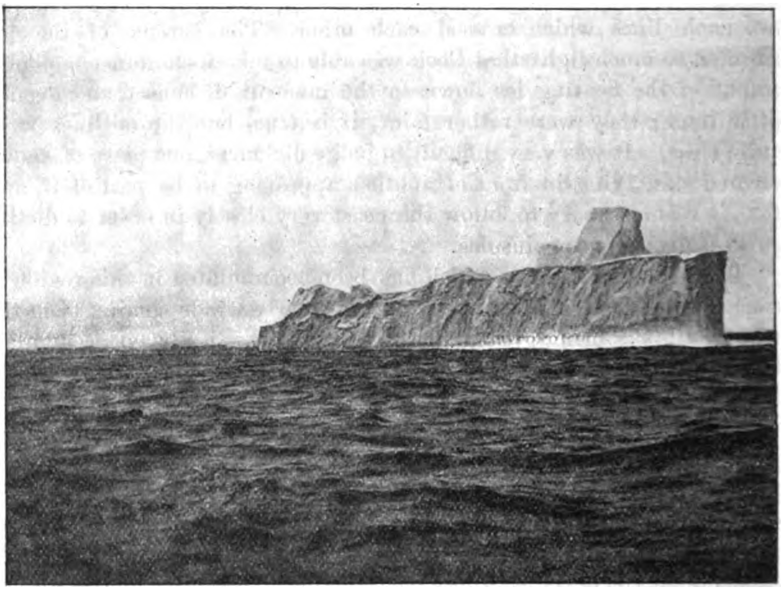


FIG. 3.—A TABULAR ICEBERG.

delicate instruments were got ashore on the steep rocks. By dint of hard work and by division of labour, we were ready to go on board again by ten o'clock. Lecointe had been able to fix the position of this fourth landing* exactly, and also that of Two Hummocks island, which lay right opposite. While Racovitza was studying the patches of moss and lichens which were found here and there on the rocks, the doctor and I made use of Canadian snow-shoes to visit the higher part of the island, and we found them a great aid in crossing the snowy slopes, which were usually gentle, though there were dangerous crevasses in places. A thick mantle of snow stretched to the crest of the promontory and stopped abruptly, the further side being perpendicular. Great blocks of ice must sometimes fall over this precipice. I ventured to cross a longitudinal crevasse, and found myself upon a somewhat unstable mass of ice, poised on the edge of the cliff. A cape which was visible a short distance to the south showed exactly what usually happened. It was too steep for snow to rest upon the seaward slope; but a thick snow-

* Lat. 64° 6′ 24″ S., long. 61° 59′ 30″ W. of Greenwich.

field occupied the top, and numerous vertical furrows marked the places where avalanches had occurred. At the base there was a mass of snow piled against the rocks, its lower portion hardened into ice.

The heat from the sun reflected by the field of snow was so intense that I preferred not to continue the walk with Cook, but sat down in the midst of the silent solitude to allow the grandeur of the magnificent polar landscape to produce its full impression on my mind. To the south and south-east the head of the great bay was formed by a stretch of land extending as far as one could see. It was a region quite Alpine in its character, but completely buried by glaciers. The snow-fields rose towards the interior, forming a veritable ice-cap, terminating in a perfectly continuous sky-line. Peaks, mountain ranges, and profound gorges there might be; however, they were not to be seen, but lay buried beneath the inland ice. Lower down the relief of the land could be divined beneath its robe of snow, and here and there a bare peak pierced the covering. Nothing like an exposed chain of mountains was to be detected, although near the sea a coast range could be made

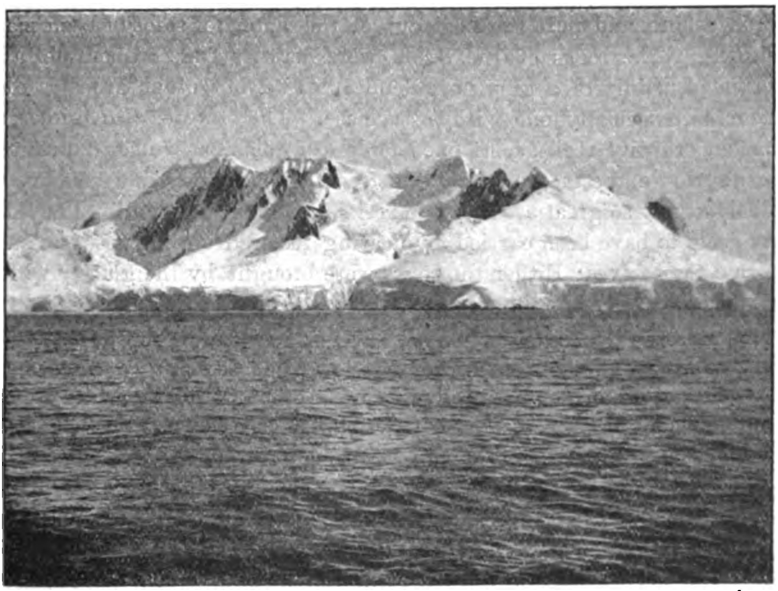


FIG. 4.—GLACIATION OF NORTHERN ISLAND OF PALMER.

out, its sides cut by valleys, through which glaciers of various sizes made their way. Along the shore some of the promontories were bare, but on the lower ground the ends of the glaciers were covered by a field of snow, and were for the most part confluent, forming a platform of ice

which gave origin to icebergs. That valleys exist, though they do not show on the surface, is clear from the differences in the size and appearance of the glaciers. The largest are of gentle slope, the smaller steep and broken by numerous crevasses. Some of the glaciers suspended from the cliffs were of extraordinary dimensions. Thus, by the appearance of the surface of the ice, and nothing else, one could see that the configuration of the buried land was complicated, and underneath each glacier there must be a great excavated valley, along the bed of which the ice glides downward. The proof of the existence of valleys is very interesting, for it points to a time when there was no ice, but dry land being eroded by the running water of rivers. On the other hand, the thought of these buried valleys brought to my mind the channels of Tierra del Fuego, as they must have appeared in the glacial period, when the end of the Andean chain lay under just such an ice-sheet.

At 11 a.m. we were once more on board the *Belgica*, steering north-east in order to follow and survey the south-east coast of Palmer land. At 2 p.m. we were opposite a cape where the coast-line changed its direction, and here we made our fifth landing at the head of a little bay where the pebbly, boulder-strewn beach sloped so gently that we had to wade ashore, and pull the boat out of the water for safety (V on map, Fig. 2). The rocks of the beach were erratics from a moraine, and consisted mainly of a grey hornblende granite, but other granites also occurred, especially one with orthoclase. There were also numerous ancient eruptive rocks, some fine boulders of gneiss, as well as quartzites, porphyries, and a metamorphic schist. It was a fascinating problem to consider how so great a variety of rocks came together here. They did not seem to have been carried by floating ice, and two hypotheses suggested themselves: Either the rocks were brought by the glacier which entered the head of the bay, or they dated back to a time when the glacial conditions were very different from those now prevailing. The former hypothesis seemed improbable, for the stones were worn, as if they had come from far; although this argument is not a very strong one, since the waves had made their action felt also. On the other hand, the relief of the land was opposed to the formation of an important glacier at this place. The mountains which border the island along which we had been sailing are very near the shore, very steep, sometimes even perpendicular, and their crests are often completely free from ice. Only the lowest part of the flanks of the mountain are covered with suspended glaciers separated from the snow-fields above, and terminating either on the beach or beyond it in the water. Hence the ice which enters the bay cannot come from any great distance, and the material which it carries must be that of which the mountain is composed. Again, the variety of rocks in this moraine is too great to be derived from the neighbouring mountains; they unquestionably come from different places extending over a wide region. Hence, if these rocks are

not to be found in Palmer land, they must come from a southern continent, and have been deposited here as the lateral moraine of a vast glacier which must have filled up the whole of Hughes gulf; and in any case there is evidence of a former great extension of glaciers—that is to say, of a glacial period. Lecointe made an astronomical observation.*

At 4 p.m. we were under way again, steering S. by E. towards the island where we had first landed. The sky was somewhat overcast, at first by flame-shaped cirrus, then by alto-cumulus, the cirrus becoming transformed into cirro-stratus, and, finally, before sunset a low haze formed on the sea, grew thicker for a while, but shortly after sunset it cleared once more, and we saw the islands and mountains in the south quite distinctly.

Wednesday, January 26, was entirely spent between Two Hummocks island, the island of our first landing, and two groups of islets situated

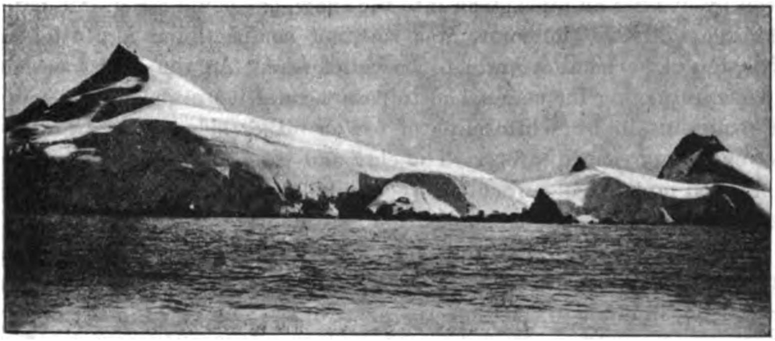


FIG. 5.—THE MOUNT NEAR FIFTH LANDING.

further north. In the afternoon Lecointe, Danco and Racovitza landed on the island of our first landing in order to make magnetic and astronomical observations, while Cook, Amundsen and I landed on Two Hummocks island (VI on map, Fig. 2). Taken as a whole, this island presents a very characteristic form; it is narrow and entirely covered with a thick mantle of snow, which gives it a convex appearance. Two pyramidal mountains project like nunataks, contrasting with the general smooth outline; these two hummocks are ranged in the direction of the length of the island. We landed on the north coast in the hope of being able to climb one of the mountains, and found that the shore was formed by a cliff of ice with only a few promontories of bare rock. I did not see the ice actually immersed in the water at any point; a very narrow strip of bare rock always separated it from the sea. Where we landed the shore was bordered by *roches moutonnées*,

* Lat. 63° 57′ 4″ S., long. 61° 47′ 34″ W.

either awash or rarely rising so much as a yard or two above the surface. A little snow rested even on these rocks, and the sea-leopards were sleeping upon them very tranquilly. Along the coast there are deep crevasses in the ice, so that the cliffs have all the appearance of an icefall. The rock of the island is a grey granite, with thick and very regular veins of a dark and compact green rock, and also smaller red veins. There were some erratics also, but these might very well have been carried by floating ice. In attempting to ascend the island, we were stopped in a fog, when at a height of about 350 feet, by crevasses which we could hardly see, although on returning we were able to make out snow-bridges by which we could have crossed some at least. The crevasses lay parallel to the shore—that is to say, at right angles to the slope. We did not see ice exposed at any place, although in the crevasses there was a fine blue colour, but that this was not necessarily due to ice is shown by the fact that, on making a hole about 5 feet deep by driving an alpenstock into the snow, one could see in it a patch of intense blue. The snow was soft, not compact, but agglutinated, although of too small a grain to be called *névé*. As the boat was some time in returning for us, we had to pass several hours on a little patch of rock shut in by white cliffs of ice on either side, which we could not even approach in safety. The clay and sand lying in the hollows contained no trace of animal or vegetable life; there was nothing but bare polished rock, a few pebbles, and in the water some seaweeds and a very few molluscs. The fog cleared in the evening; the boat came at last and took us on board. We continued to survey the islands as we passed, in order to complete the chart of the north of the bay.

On January 27 we landed at 10 a.m. on a little islet not far from Two Hummocks, where there was no snow-covering, though its highest point was 100 feet at least. The islet (VII on map, Fig. 2) was scored by numerous cracks which cut the rock into lozenge-shaped pieces and covered the surface with angular fragments, the whole resembling the lofty crests of the granitic masses of the Alps. The only snow to be seen remained in the dark recesses of the cracks. The island was a rookery of penguins and cormorants, and in places some guano mixed with clay and birds' feathers was found.

Towards the afternoon the *Belgica* steered south-westerly, and in the evening we entered the large strait stretching towards the south, which turned out to be very wide, and in parts we saw high mountains and great glaciers enclosing the headlands, and in one case at least extending beyond the coast into the sea.

On Friday, January 28, the weather was foggy, and we made a sounding in the centre of the channel, finding a depth of 342 fathoms. We were surrounded by whales (*Balænoptera*), whose blowing could be heard constantly, a mysterious sound to break in upon our solitude as we floated between the grey sky and the dark surface of the sea, on

which they played without paying the least attention to our presence. We approached the coast in order to attempt a landing. Amongst several islets and rocks there was one which presented an appearance of stratification with a slight dip: it was flat and almost completely bare, showing that the snow-line here does not descend to sea-level. We could not see the mountains, for only the lowest part of the coast appeared beneath the clouds. A very large moraine, almost completely bare, was seen running along the shore in a north-east and south-west direction. There was a good deal of floating ice. We saw several places where there were great cliffs of ice with curved indentations, doubtless marking the places where icebergs had broken off; the crevasses on Two Hummocks island represented complete fractures, which only required a slight impulse to launch the detached berg.

At dinner there was a great discussion between Lecointe and de Gerlache as to whether these were islands or a continuous coast—a question of great difficulty, for what with the fog and the uniform white glare without shadow or perspective, it was quite impossible to make out the detail of the land. For geographical purposes an approximate sketch-map is not to be tolerated; it is little use to advance far into an unknown region if all that can be inscribed on the map of the Earth is the track of a ship. Such a result, no doubt, is highly creditable to a navigator, but a scientific expedition ought to have other aims. Lecointe was certainly right to insist that the work which had been commenced must be carried through.

At 2 p.m. we landed on the island one mile from shore, which showed an appearance of stratification (VIII on map, Fig. 2). It was difficult to get ashore on account of the sea, but when we succeeded we found that the whole surface was a smoothly glaciated rock of eruptive origin, traversed by veins 20 feet thick of a grey compact substance. A little snow remained on the island, but the fog prevented us from continuing our survey, and the wind and sea were rising, so we had to return on board.

On Saturday, January 29, the weather was calm again; the fog had cleared away and revealed a marvellous scene. On every side the thick white covering descended to the sea, and only the steepest slopes were free from snow; perpendicular cliffs and steep hill-sides were characteristic of all these coasts. A cliff which bordered a submerged valley where an immense glacier debouched showed an appearance of vertical stratification, but our ninth landing enabled us to prove that this appearance was due merely to cracks in the rock, as in all previous cases. This may possibly be an effect of extreme cold, for the *roches moutonnées*, which are preserved from abrupt changes of temperature by snow covering them most of the year, do not exhibit such cracks, or only to a slight extent. It was a curious landscape in white, grey and black, yet with plenty of light, although the sun was hidden, and a

wonderful play of shadow. Photographs can say nothing as to the complex tints, while painting often exaggerates them; only an exceptionally good colourist could record the delicacy of the tones. My Russian friend, Pokhitonow, would make an admirable picture of this landscape, so imposing by its severity. The sea was very dark, slightly greenish in the foreground; the horizon loaded with black and grey stratified clouds, and in the whiteness of the stratus above there was a yellowish tinge. The snow was very white, and the glaciers of a white just faintly bluish towards the base, and in the cracks and below there was the blue of the water; the rock was black, in places touched with brown, and lines of yellowish grey; the clouds, merely elevated fogs, encroached upon the summits of the mountains, gradually thickening upwards.

In the afternoon, while waiting for the sun and a wider view, we landed on a floating cake of ice in order to obtain a supply of fresh water.

At 5 o'clock we landed for the ninth time at the foot of a perpendicular rock; elsewhere a high cliff of stratified snow passing gradually into ice in its lower part, made landing impossible (IX on map, Fig. 2). The crevasses, which form parallel to the shore, cut this wall of ice into sections. The head of the little bay which we had entered was occupied by the front of a large glacier, which terminated in a *mer de glace*; and here we were happy enough to be present at the formation of a very little iceberg—a great block of ice which tumbled into the water with much noise, raising a cloud of dust from the ice, and starting a series of waves across the bay not large enough to hurt our boat. This glacier rises slowly towards the south, and its mountainous border runs north and south. A very characteristic island resembling Two Hummocks lay in front of us. In the evening, as we were still in the same neighbourhood, I made a drawing to show some large curved crevasses which were very sharply marked, and proved that the ice flowed most readily in a direction at right angles to them. Except for two mountain peaks, the island is completely buried under a thick layer of ice, which is undoubtedly a glacier, and, though differing in appearance from valley glaciers or suspended glaciers, is nevertheless subject to the same laws (Fig. 6).

The night was fine, and the *Belgica* remained in the same position in order to get her bearings next day. The sea extended to a distance towards the south and east of the prominent headland, where our ninth landing was made; there was evidently a great bay, and possibly a passage, but the way seemed to be closed by lofty mountains with majestic peaks. Towards the north-east was the channel which we had undoubtedly entered in too great a hurry, and we had to return on our track in order to make a connection with the land previously discovered. There was also a passage in the north-west, but my attention


FIG. 6.—TWO HUMMOCKS ISLAND.

was particularly attracted by the fine mountain summits of the large island which lay to the north of our position. While pacing the deck with Lecointe, I pointed out to him a place where I thought a landing might be made, and we discussed the possibility of an attempt to climb the mountains. In the distance a gentle and very regular slope could be seen stretching up to one of the peaks, attaining an elevation of about 7000 feet, and it seemed quite possible to ascend in this way and from the summit to sketch the outlines of the land very easily, and obtain a general idea of its configuration. Lecointe was prepared to adopt Admiral Mouchez' method of surveying by utilising the height as a base, and fixing the distance of points on the coast by measuring the angle with the vertical. Cook was ready to accompany us, and Amundsen did not wish to be left behind.

On Sunday, January 30, we steered north-north-east, in order to land at the foot of the mountains of our ambition. The commandant decided to accompany the land-party, but in that case the *Belgica* would be left without officers, to which Racovitza objected. Lecointe consequently had to remain on board, and Danco, who was to come with us, undertook the theodolite work; but the preparations which had to be made were too elaborate, and the projected excursion was doomed to failure before it started. In order to succeed, it would be necessary to carry supplies on our backs and make a great and sustained effort, being prepared, if the route was bad, to return and choose a better way; for at present we could no longer see the gentle slope which had been visible from a distance, and it was by no means certain that the point at which we were to land would turn out a favourable one. We took with us two sledges of Nansen's pattern, sleeping-bags, a silk shelter tent, a little

aluminium stove, such as was used by Jackson, Norwegian *ski*, Canadian snow-shoes, ice-axes, a 40-foot rope of raw silk, provisions for a fortnight, even changes of underclothing, and all the instruments after that. Certainly there was far too much baggage, and we were not likely to go so far during the eight days we intended to pass in the glacier; still there was no knowing whether we should not find something interesting to observe. We landed on a little promontory at the head of a fine bay, where a large glacier entered the sea and the snow lay down to the water's edge (X on map, Fig. 2). There was no difficulty in getting ashore, but the sledges were horribly heavy. Lecointe, Tollefsen and Johansen helped us to make a start, and then we continued by ourselves, a party of five, de Gerlache, Danco, Amundsen, Cook and I. The *Belgica* left the bay to continue her surveys in the south, and to return for us later. At a height between 400 and 600 feet we had to cross several crevasses, which were narrow and spanned by snow-bridges solid enough to allow our loads to pass without difficulty. Higher up, a great snow-field stretched before us, whence we could look down upon the glacier which cascaded towards the bay. The ice from this dislocated glacier could only break off in small pieces, so that we recognised that the essential condition for the formation of icebergs is a slope gradual enough to prevent the formation of a *mer de glace* at the extremity. The night passed comfortably, though we were too tightly packed in our tent. After breakfasting on the everlasting oatmeal, we set out with our loads, but it was too foggy to allow of much progress being made. While waiting for the fog to lift, we pitched camp for the second time, and no sooner had we done so than the weather became fine.

Cook and I set out for a reconnaissance upon the glacier, which formed a continuous plateau rising gradually towards the interior of the island, where two mountain summits rose above the snow. The conditions appeared to be most favourable towards the north-west, and the whole party set out with the sledges in that direction, and we encountered only a few small crevasses, which were easily crossed, then the slope began to increase. At 2.30 p.m., during lunch, I placed the black-bulb thermometers on the snow, and, although the sun was slightly veiled, they showed readings of 102°·6 and 86° Fahr., although the temperature of the air, measured by a sling thermometer, was only 34°·2. The strength of the solar radiation made us all feel very warm. We enjoyed a very extensive view towards the south, and saw the high mountains on the opposite side of the strait diminishing gradually in height towards the east; the direction of the chain seemed to be north-east and south-west. The whole of this mountainous region seems to have subsided, but, if the west of these lands has sunk, it may be that there is a large plain of upraised land to the east, the low relief of which would cause the glaciers to be prolonged into the sea, and in such conditions icebergs formed upon the continental shelf itself might attain a

great size. Here, on the contrary, most of the coastal glaciers are of a different type, terminating at the level of the sea. At 7 p.m. we were still mounting upwards, the weather being remarkably fine, and the view of Graham Land grew finer and finer. The relief of that land, although excessively varied, is singularly softened by the glaciers and the accumulated snow, so that it is only because the valleys hollowed by the running water of some epoch are so deep that some crests and very abrupt slopes remain bare. At the height of 1600 feet we were stopped by a crevasse over 30 feet wide, which we could not cross, and other crevasses appeared beyond it, the whole glacier having a terraced structure. We had consequently to descend again to the ice-plain in order to camp for the night. During the whole of Tuesday we were dragging our loads uselessly towards a hill in the west, but in that direction also we were stopped by numerous crevasses, and, in any case, if we had reached the hill we should only have been able to see a part of the horizon. Again we had to retrace our steps to the ice-plain to pass the night, and there we left our camp for the two following days, seeing that it was impossible to reach any high summit. We climbed two nunataks in the east, one of which was easily ascended, and on it Danco and de Gerlache made observations with the theodolite. The minimum temperature of the night between Tuesday and Wednesday was 25°·5 Fahr., and between Thursday and Friday 24°·6 Fahr.

The radiation from the sun during the three days had not sufficed to change the snow into *névé*. On Friday I went over the whole of the plain, and found snow at the surface everywhere, but at a depth of 4 inches there was frozen *névé*. The plain, upon which we camped, is the result of the complete filling of the valley; for it is certainly a valley which descends from these heights, but it is very difficult to give the orography of the lower parts, as the glacier and the accumulation of the eternal snow hid the form of the land. The formation of the ice, however, showed me that the nunataks are the summits of the sides of the valley, and the cascade that we vainly tried to cross is the step which would have led us to another plain of ice, covering a second terrace of the same valley. Amundsen and Cook tried to pass the crevasses by climbing along the walls of rock which bordered that section of the glacier in places, but they were unable to reach their goal.

From the summit of the more distant nunatak Cook and I had a good view of the *mer de glace* in which a large glacier terminated at the head of the bay where we landed; although the broken fragments could not give rise to icebergs as they entered the water, it seemed quite possible that in winter, when the bay is frozen enough, ice might accumulate to form one or more bergs. In any case, it appeared certain to me that the bottom of this great valley extended below the level of the sea; and I was also led to believe, judging from the distances which separated the nunataks and the angle of slope of the walls, that the same holds

good for the valley in which we were camped. We found some lichens and mosses on the nunataks.

On Saturday night we heard the *Belgica* return, and on the morning of Sunday, February 6, we heard her whistle again. We could not go on board, however, because the wind was blowing too strong, and Amundsen, who went to look out, saw the ship leaving the bay. We changed our camp, and, as the wind was always tearing the tent, we were obliged to protect it by a wall of snow.

On Sunday afternoon we all got on board the *Belgica*, and found that Lecointe and Racovitza had made two landings in our absence. We steered towards the east, in order to continue our survey of the coast of Graham Land. The air-temperature was high all day, with a maximum of 45° Fahr. At night it rained, at times very heavily, and it must have produced a great effect upon the snow-fields, because we noticed in descending the plateau that the snow had considerably changed its appearance, and we sank deeply in the porous mass. The rain must have produced a much greater effect than a day of strong sunshine.

On Monday, February 7, the sky was overcast, but the weather was clear and the sea calm, and we passed quickly along the southern coast close inshore. The coast was very remarkable, on account of its great indentations. Hughes gulf was followed by a bay, which we had rapidly sailed round, and then came another still larger, of which we followed the shore; but further south Lecointe found yet another bay, in which very large glaciers terminated. We passed so close to the shore that we could not see the high mountains in the interior of the country, but only the ends of the glaciers coming from the inland ice. On the other hand, we could study in detail the innumerable glaciers which are attached to the flanks of the mountains bordering the strait. The rocks are very steep, and in many places exposed to view, but too often in inaccessible positions. We succeeded, however, in landing at the base of a granitic cliff, near which, upon a little promontory, I discovered a metamorphic schist in contact with the granite (XIII on map, Fig. 2). The direction of the strata was north-west and south-east, and their dip towards the north was about 45°; a very friable schist alternated with a dark quartzite and dark green strata of a highly metamorphosed rock. The granite is below, i.e. in the south, and forms a mountain, close against which is a mountain of dark rock quite inaccessible except for one cliff, at the base of which I was able to risk myself. The stratification seemed much straighter above than at sea-level. From midday the weather was bad, with rain, snow, and fog, but at night it grew finer.

On Thursday morning I went up in the crow's-nest in order to photograph with my binocular camera the three-quarters of the horizon from north to west. It was splendid weather, and here one was absolutely alone, with nothing and no one to distract the attention.

Even from the mast-head it was impossible to see far into the interior of the land; only the first wall of the mountains was visible. The region in which we now were seemed to be much less buried in ice than the land at the head of Hughes gulf, and the glaciers appeared to be local, coming from no distance in the interior. It is also noteworthy that here the peaks rising as nunataks and the walls of rock bordering the glaciers are sharp, and only rounded by ice-action for the 500 feet nearest the sea. In the neighbourhood of a great glacier coming from the south, where the twelfth landing was made by Racovitza and Lecointe, there was a very large *roche moutonnée* in front of the end of the glacier, which is evidently retreating. A little further to the north of that point I saw a nunatak, at the base of which the ice seemed also to be retreating. On the northern side a very characteristic curvature (*a*, Fig. 7), with a smoothed surface, was remarked near the snow, while there were large vertical grooves above. I saw very few examples of this kind; as a rule, the nunataks were well buried.

FIG. 7.—NUNATAK, AT THE BASE OF WHICH THE ICE WAS RETREATING.

The tenth landing (X. on map, Fig. 2) was on a large island. I saw the channel which separates it in the south-west from another land, and to the north-west the sea horizon was unbroken — it was the Pacific ocean. I saw this confirmation of my theories * with much pleasure; there was no doubt that we were on the west coast of the continental land symmetrically placed with regard to the Southern Andes. There is no passage to the east, and the Biscoe islands form a parallel chain belonging to the mountain system of Graham Land.

We continued to approach the north-west coast, our course being west-south-west. I noticed a wall forming a little cirque between two promontories, at the foot of which a broad glacier terminated abruptly along the shore and stretched upwards towards the mountains in a gentle slope. A series of curved lines, more or less parallel, could be distinctly seen upon this wall; the last of them followed the outline of the field of *névé*. There were ledges of the rock ranged like steps;

* *Bull. Soc. Géol. France*, 1895, p. 590.

the snow lying on the flat shelves contrasted with the dark colour of the steep slopes and thus emphasised the structure. The same thing was seen in other places where similar conditions prevailed, and it seemed that these steps were old levels of the snow-field, and their existence proves a former greater extension of the *névé*. While the *névé* remained at one level, the exposed portion of the rock wall crumbled under the influence of atmospheric agencies, while the part covered by snow was protected, hence the cutting of the step.

At noon, Lecointe, Danco, Racovitza, Amundsen and I landed with the instruments necessary for astronomical and magnetic observations;

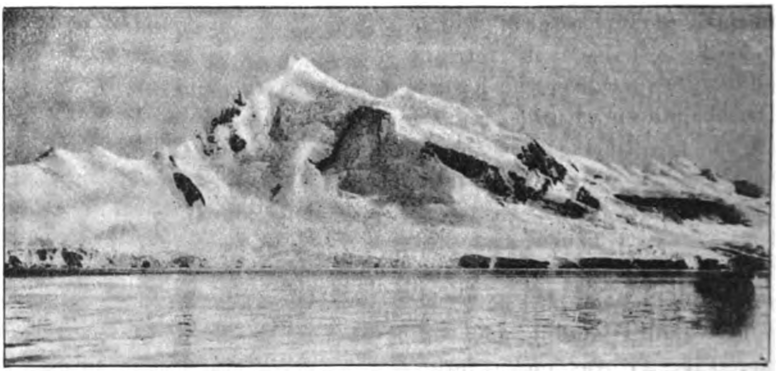


FIG. 8.—MOUNT WILLIAM.

but, unfortunately, we were too late to observe the meridian altitude, a misfortune the more regrettable because Lecointe had urged the commandant to allow us to land sooner. We remained some time on the strip of bare rock which was exposed between the field of *névé* and the sea. It was the same black granitoid rock traversed by thick veins and narrow threads of quartz; and there was a great variety of erratic blocks, including specimens of basalt, breccia, several blocks of conglomerate, and some fragments of quartzite. A cave was found in the large-grained, porous ice-wall, along the uncovered bed of which a little stream flowed, the first glacier stream I had seen. It came from the direction of a nunatak, and consequently could not have pursued its course to a long distance under the ice; in its bed there were rolled pebbles of eruptive rocks. We were only two hours ashore, so it was impossible to get as far as the nunatak. At our landing-place, and for some distance out from the shore, we saw the bottom of the sea very distinctly, and in some places could even touch it with the oars; it was composed of pebbles and boulders.

At 5 p.m. the *Belgica* resumed her voyage southward, and we entered

a channel which narrowed as we proceeded. The mountains on the right became lower and their profiles sharper, while on the island to the east of us I saw the snow-fields on the summits merging one into the other, and forming plateaux of ice. A little sierra, composed of five or six peaks in a row, ran in a north-east and south-west direction, and, as we were abreast of the first mountain, it presented itself to us as an abrupt wall of rock, the screes at its base partly buried by snow. The other summits further south were much higher. The channel itself had the appearance of a fjord, but there were no mountains at the end, only a low snow-field, and signs of a passage towards the west. As we advanced, the mountain chain on the right became clearer; in the west there was only one high mountain,* and beyond it doubtless the ocean. The sierra on the left showed no trace of stratification. At 7 p.m. we found that the channel curved towards the west almost at right angles, and we entered another channel parallel to the first. There was very little floating ice, and not one iceberg was to be seen. The channel we had entered continued as a great valley into the interior of the island, a glacier descending along its gentle slope from the north. The chain which formed the mass of the island culminated in a high summit entirely snow-covered in the north, and gradually fell off to the south. It would really take years to work out this complex of channels, inlets, and islands, and many facts of general interest would be elicited if the archipelago were to be thoroughly mapped. At eight o'clock we passed some of the flat suspended glaciers characteristic of the island on our left, and a diagrammatic section of one of these is given in Fig. 9. They have always the long crevasses, sometimes slightly curved, with detached berg splinters. The general appearance of these coastal glaciers is a great mass of snow heavily heaped against the mountain. The surface has a slope far too gentle to produce the effect of a suspended glacier of the Alps, or even of the channels of Tierra del Fuego. The sun set in an orange-tinted horizon, the sky above being intensely blue, with little golden clouds, and the mountains facing the sunset flushed pink and changed to red. It would be difficult to imagine any place more beautiful in such perfect weather; the everlasting ice, the grim mountains, and the majestic silence combined to impress the mind with an overmastering sense of the calm

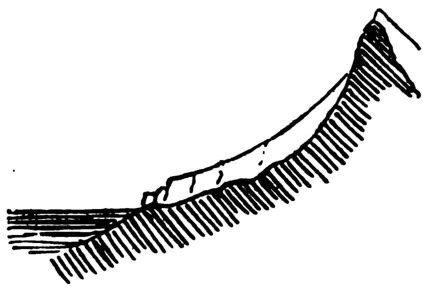


FIG. 9.—SECTION OF SUSPENDED GLACIER.

* Biscoe's Mount William.

severity of nature. Alone in the crow's-nest, I rejoiced at my good fortune in attaining so great a reward for my voyage as this feast of grandeur and beauty.

On Wednesday, February 9, at 7.30 a.m., we made our fifteenth landing (XV on map, Fig. 2). The whole coast appeared like one great *roche moutonnée* entirely free from snow, everywhere smoothly polished and scored with sharp grooves, often very deep, running in all directions and crossing each other. The larger were vacant, but others were filled with thin leaves of rock, and some with compact grey veins, giving the rock a schistose appearance. The surface of the granite was strewn with splinters split off by the effects of radiation, usually from one-third to two-thirds of an inch thick, and about a foot in diameter. There were no erratic blocks. The rocks were bare up to a height of about 150 feet, but from this level the snow uniformly covered the island. The sheet of snow gave rise to a trickle of water, forming cascades, under which an abundant vegetation of mosses and algæ had accumulated. A few tufts of moss were found here and there among the stones. The sun shone strongly, and the bare rock grew quite warm. At 8 a.m. on the *Belgica*, when the air-temperature was 41° Fahr., the black-bulb thermometer in the sun read 87°·8, hence the splintering of the surface of the rocks could easily be understood.

At ten o'clock we were on board again, heading south out of the channel, and as we passed along the coast I saw several semi-cylindrical ice-caves from which streams issued, but the tunnels were small compared to the great mass of the ice. At 10.30 we passed the cape at the south end of the mountainous island we had been coasting, and the recording thermometer fell, while the hygrometer rose sharply, as the influence of the ocean made itself felt; and in the distance great icebergs could be seen in the open Pacific. I counted a group of twelve small, low islands, mere domes of snow, bordering the large island in the south-west; and at eleven o'clock we made the sixteenth landing on one of them (XVI on map, Fig. 2). Lecointe landed for the noon observation of the sun, making use, as before, of an artificial horizon; Racovitza, Cook, Danco, and I accompanied him. The whole islet was covered with moist snow almost to the water's edge; it was strange to see so great a difference in the height of the snow-line in so short a distance as that separating the XV and XVI landings.

These low islets are more exposed to the humid winds from the western ocean, and consequently receive a greater precipitation, the snow not all melting in summer. On the snow we found penguins' feathers, shells carried by the birds, and all kinds of dirt, producing hollows by absorbing heat from the sun, and sometimes these holes were rather deep. The *névé*, which was all oozing with water, was compact at a trifling depth, where it changed into ice. The ice-cap of this islet was crossed by a single narrow crevasse. The rocks round the edge

were all iceworn and very flat, in some places scored with cracks, though to a much less extent than at the place of our previous landing. There were numerous veins of quartz, some quartz in the form of amethyst, and a quantity of copper ore. There were no erratics. All the islets of the neighbourhood had the same appearance, like great whale-backs appearing above the sea. The polished surface extended to just below the surface of the water, and there were also, near the islet where we landed, several glaciated rocks scarcely emergent.

The whole group seems to form a plateau which has been profoundly glaciated, and of which only the higher portions now appear, but this plateau has nothing in common with the continental shelf, the whole of the district which we have explored presenting very clear evidence of a submerged region. From another point of view, these islands are by no means the stumps of mountains worn down by marine erosion; they afford evidence of a great extension of glaciers in some by-gone period. The whole channel, which we were now about to leave, had doubtless at one time been filled by a great glacier which flowed to the Pacific. The cutting off of the summits of these islands may be its work.

At 3 p.m. we turned the southern point of the sierra and steered north-eastward in order to continue our exploration of the main channel, which is divided by low islands into several branches. It is a question of some interest whether it is the Bismarck strait of Dallmann. The sierra reappeared suddenly in the south, on the other side of the entrance to the channel, and continued in a straight line to the south-south-west, but a lower parallel ridge appeared west of the main chain, and beyond it a range of islands, the summits of which were still lower, bordered the coast, the whole evidently forming a tectonic chain. Towards the interior a gentle slope of glacier connects the sierra with a higher mass buried under the inland ice. At 4 p.m. we made the seventeenth landing on an islet not far from the east coast of the island we had come round (XVII on map, Fig. 2). Racovitza, Cook, Danco and I were left ashore for some hours while the ship continued her route. The end of the island where we landed was a great rookery of penguins and cormorants, and the snow was much soiled for a considerable distance from the shore. The rocks, which are much glaciated, were fairly level, and at the heads of the little bays, out of reach of the waves, we found numerous pebbles and small erratic blocks of gneiss, various granites, and porphyry, but neither pudding-stones nor basalt; and, as I saw no erratics elsewhere, it is probable that these were carried by floating ice. A rocky hill was uncovered to a height of 70 to 100 feet, and above that was the layer of ice, which, in places of more gentle slope, descended to the shore. There was little *névé* on the surface, and all of it melting; water trickled away on every side, though not in any great quantity. The surface of the ice was traversed by vertical cracks,

running in different directions, and varying from ½ to 1 inch in width. While the crevasses had vertical sides and were hung with icicles, these narrow cracks were full of water. This mosaic of cracks occurs on the top of the boss of ice which forms the summit, while on the slopes the crevasses assume a transverse direction, being evidently produced by the tension of the ice as it creeps downwards on every side towards the sea. One main crevasse ran along the whole length of the back of the island. On the side where we landed the ice-covering was pierced by a few scarcely visible points of rock, while the whole southern shore was bordered by a cliff of ice. Another island, similar in every way to the one on which we landed, lay quite near, and on it also streams of

FIG. 10.—ANTARCTIC ISLAND COVERED BY AN ICE-CAP.

water were trickling from the ice. I made a sketch of this island, which is shown in Fig. 10.

From the eastern side the sierra had a much more gentle slope. The cirques in the crest were occupied by very steep glaciers, but lower down the wide snow-fields reduced the slopes to a very gentle gradient. The rocky walls so characteristic of the north-west of the sierra, as seen from the other side of the island, were not represented at all on this. On the northern slopes of Graham Land, on the other side of the wide channel, I saw an immense glacier descending the gentle slopes from the snow-fields which lay about the heights situated in the south-west. It was really a majestic ice-stream filling two large valleys for three-quarters of their depth, while higher up it completely drowned the rocky spur that separated them.

With Cook I walked round our islet, and at its northern end found several fragments of moraines plastered against the slope nearly 80 feet above the level of the sea, and from 15 to 25 feet in height. They contained the same gneiss, granites, and other rock collected in the little bays of the shore. The predominant rock was granite with hornblende, in fragments which were often angular; the blocks of gneiss were often very large and perfectly polished. Since the granite with orthoclase only occurs in the form of well-rounded pebbles, it doubtless has come from a distance, and the same is true of other rocks. The moraine descends very slightly towards the west, and its direction

is that of the channel. This moraine is another decisive proof of the existence of a glacial période in the neighbourhood of Graham Land. In the evening the sky became overcast, the wind rose, and it grew very cold as we waited for the *Belgica*, which at last returned for us about 9 p.m.

Thursday, February 10, was cloudy and slightly foggy, and for a time we could scarcely see where we were amongst the numerous islands, with the low clouds concealing the characteristic mountain outlines. At noon we made the eighteenth landing, almost opposite the seventeenth, on the other side of the large channel (XVIII on map, Fig. 2). It was at the base of a pyramidal mountain of red rock, very different in appearance from the surrounding scenery. A great band of red granite seemed to traverse the region from north-north-west to south-south-east. The interesting feature of this landing was the discovery of a moraine at least 70 feet in height, which was set against the mountain-side along part of the beach in the direction of the channel. The rock itself was highly glaciated to just below the level of the water.

The boulders were mainly angular fragments of red granite, and, on the crest of the moraine, numerous blocks of well-polished gneiss. There were also pebbles of hornblende-granite, porphyry, and other rocks, including a white quartzite with small crystals of pyrite, and a very compact black schist. Since we were always in sight of the coast, I never ceased to ask for more landings; I urged Lecointe, de Gerlache, and the others again and again, but not with so much effect as I could wish. The commandant showed himself very obliging; but with a little good-will we could have landed in many other places and collected much more geological material than we did. For this eighteenth landing he conducted me himself, but for ten minutes only. A few strokes of the oars brought us to the beach amid cries of "Hurry up, Arctowski!" I gave a hammer to Tollefsen, with orders to chip here and there down by the shore, while I hurriedly climbed the moraine, picking up specimens as I ran, took the direction with my compass, glanced to the left and right, and hurried down again full speed to get a look at the rock *in situ*; meanwhile, Cook had taken a photograph of the place from the ship—and that is the way geological surveys had to be carried out in the Antarctic.

At 4 p.m. we passed a fine iceberg, which appeared like the face of a glacier, and must have been recently detached, for it still bore the marks of crevasses. It was about 100 feet high by nearly 700 long.

At 5 p.m. I was again in the crow's-nest, and we were heading south-east, perhaps to cut another slice off the northern end of Graham Land. It was not clear, but we could make out enough to recognise landmarks. What seemed to be a channel turned out merely a wide fjord which got slightly narrower towards the head. The amount of floating ice and icebergs increased; some of the latter were over 500

yards, and one was certainly over 1100 yards, in length. Although there was no sunshine, we heard the thunder of the avalanches from the land. In the north-east we saw the front of a very large glacier, but the upper part was swathed in cloud. At the head of the fjord there were no rocks to be seen; a wall of ice met the water all round—the nature of it, however, was not quite the same at every point.

On Friday morning at 9 o'clock we made the nineteenth landing on a little islet, or rather a big *roche moutonnée* under a great shield of snow, rising gently from the water (XIX on map, Fig. 2). The strip of bare rock between sea and snow reached only 2 or 3 yards above the level of the water, and was remarkably smooth and glossy. There were two islets of this kind, and between them a moraine just appeared above the sea; it consisted of very large blocks of rock, probably diverse, but I could not get to see them. Lecointe, who landed for an observation on this island, was certainly very hard pressed for time.

The weather cleared a little in the afternoon, and we continued to search for a passage to the east, but there was none—it was merely a fjord. I only caught a glimpse, in a clear moment, of one of the lofty summits which must exist to the east, from which the great glaciers flow. From the head of the fjord valleys radiate inland like fingers from a hand, each filled by a great glacier. Some of the glaciers at the head of this fjord were very large; descending by an easy gradient, they formed a broad flat base, which launched great table-topped bergs of much regularity. In turning to the west after completing our circuit, we met more floating ice. About 6 p.m. we were surrounded by ice, and in fog, which remained at some little height above the water. Here we observed a strange and very beautiful phenomenon. At a given moment the ice suddenly assumed an intense blue colour, of extraordinary purity, a little tinged with purple near the horizon, and becoming lighter higher up, changing into a steely tint above, but showing no trace of green. Fog and ice were coloured alike, hence they must both have been illuminated by blue light. In the south-west, about 15° above the horizon, the blue disappeared and was succeeded by a luminous steel-grey sky, and above this white light a yellowish stratum faded off upwards into a faint orange glow, and finally, beyond 25° above the horizon, the whole sky was a dull grey mass of cloud. The phenomenon was at its maximum intensity about 7 p.m., when the sun was 18° 30′ above the horizon, and at eight o'clock it had become very faint. The air was clear enough to allow us to see floating ice a mile away. Soon after eight the fog closed in again, and when going dead slow the *Belgica* collided with a small berg, but the shock was not severe, although the bow-sprit was damaged.

On Saturday, February 12, a good deal of floating ice was in sight in pieces of all sizes, and there was a little field-ice. The sky cleared, and high mountains appeared in the south. At 9 a.m. two rocky points

loomed out of the mist, and there seemed to be a passage between them. We followed the coast very closely, and soon found ourselves in a bay, on leaving which we admired a very fine cape which rose in two lofty

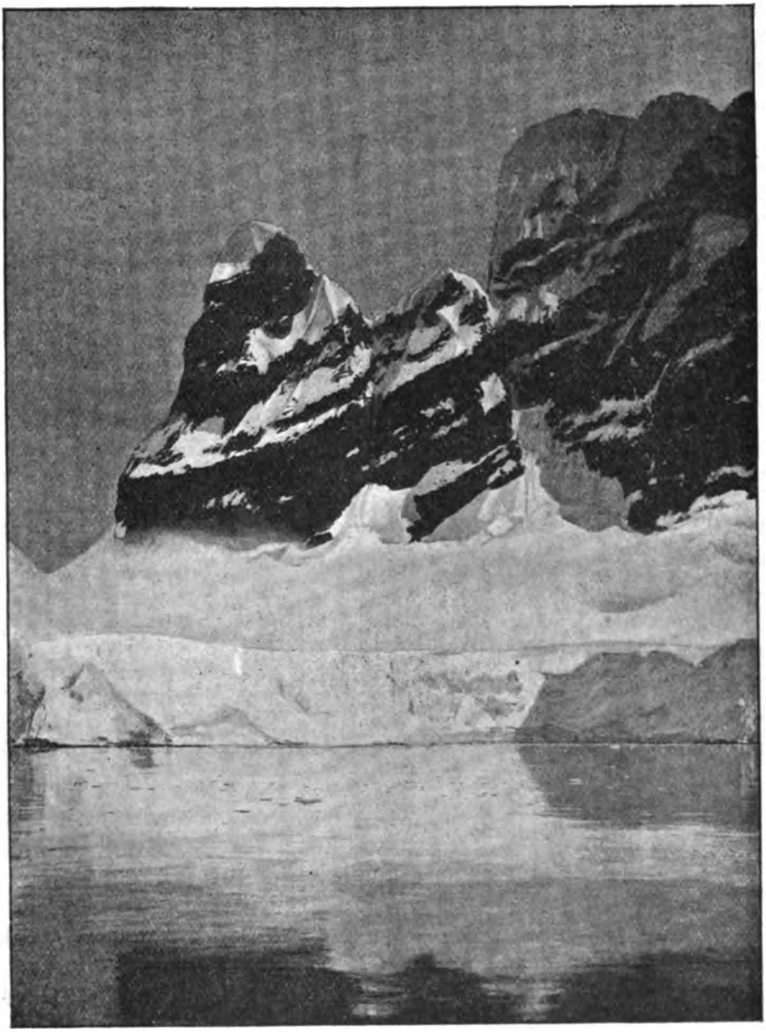


FIG. 11.—ONE OF THE NEEDLES FORMING THE NORTHERN EXTREMITY OF GRAHAM LAND (DISCOVERED BY BISCOE).

needles (Fig. 11). It was the most westerly promontory of this part of Graham Land, for the coast changed its direction here and turned towards the south-south-west. We rounded this point, and left for the time the strait which connects Hughes gulf and the Pacific.

At 10 a.m. we made our twentieth landing on the Pacific slope of the Needles, which form the northern cape of Graham Land, to make magnetic and astronomical observations and collect what objects of interest we could find. This landing-place (XX on map, Fig. 2) was quite similar to that on the coast west of the sierra. In places the beach was quite free from snow; elsewhere there were little glaciers clinging to the slopes of the mountain and terminating seawards in cliffs of ice. The steep rocky slopes above were absolutely bare up to a height of 700 or 1000 feet, and beyond that rose fields of *névé*. Cook and I climbed a little ridge running at right angles to the range of the Needles. An inclined plain of snow, interrupted here and there in the upper part by transverse crevasses, which were easily

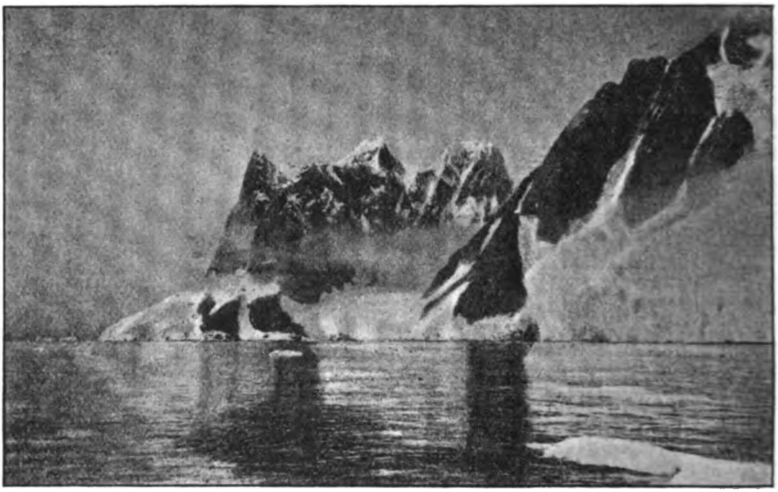


FIG. 12.—THE NEEDLES, SEEN FROM THE PACIFIC.

crossed, led us to the rocky wall, which there was no difficulty in climbing, thanks to the numerous joints widened by weathering so as to cut up the face of rock into superimposed blocks, and thanks also to the narrow chimneys down which the *débris* of the rock slipped. It is remarkable that these rocks remained quite bare at an elevation far above the snow-line. It is not sufficiently accounted for by the steepness of the slope, though that would make it possible for only a small quantity of snow to accumulate; but the dark walls were so strongly heated by the sun that the snow was actually melted. In making the ascent we found that the low cloud, so characteristic of these regions, was very thin and level on both sides. We passed through the belt of mist between the altitudes of 150 and 300 feet, and above that there was an absolutely clear sky and dazzling sunshine, while at our feet the cloud

extended as a smooth grey sea. If such a condition often occurs, it is easy to see how the higher rocks become free of snow in summer, while those near sea-level remain covered. At 3 p.m. the mist cleared completely from the side of the land, and we were able to proceed, passing through a narrow and beautiful sound which separated a group of islands from the coast. The mountains rose almost perpendicularly at various points, and on the rocks I again noticed parallel lines following the outline of the tops of the small coast glaciers (*a*, *a*, *a* on Fig. 5; *c*, *c* are crevasses).

The *Belgica* passed on, steering south. It was a pity to leave this most interesting region, where we could so easily collect quantities of valuable scientific material, and of which we could have made a complete geographical study, now that the outlines of the great strait had been charted. We ran close along the coast of Graham Land, noting that many islets and rocks extended to a considerable distance from the shore. Many icebergs were met, and we also encountered a good deal of sea-ice. At 8 p.m. we passed several typical table-bergs, large, flat-topped, rectangular, the ice stratified horizontally with great regularity, and only a few narrow vertical crevasses to be seen. They rose about 50 feet out of the water; about 40 feet consisted of ice as white as the *névé* which capped it; compact ice was only seen near the base. Just in the line of the three icebergs of this kind which we saw, we found an enormous flat glacier spreading to the sea without any interruption in the form of an ice-fall.

FIG. 13.—MARKS ON ROCKS ABOVE GLACIERS.

On Sunday, February 13, the coast was so encumbered with ice that we had to keep out to sea towards the Biscoe islands. About 11 a.m. we traversed a little light pack-ice, and passed near some table-bergs. The melting sea-ice had a dirty yellow colour, and on examining the melted ice under the microscope, Racovitza found it swarming with diatoms. We remained in sight of the coast, and more small islands appeared. At 5 p.m. we sighted a number of fantastic icebergs, amongst which I saw many transitional forms between the table-bergs and the peaked arctic forms. I made drawings of four of them (Fig. 14). The sea was rough, and the breakers dashed against the shore and the icebergs. About 8.30 p m. we were in the midst of a labyrinth of rocks, and there were also several low snow-covered islands in sight. At 10 p.m. the *Belgica* was in a very uncomfortable situation, threading her

way between rocks on every side, on which a heavy sea was breaking: the position was about 65° 10′ S., 64° 50′ W.

On Monday, February 14, the sea was free from ice, except for bergs, many of which were in sight. We steered south-west, in the direction of a strong ice-blink; a less marked ice-blink appeared also in the east. During the day we designedly sailed over the position assigned to the Biscoe islands in the Admiralty Charts, which seem to have adopted a position so far from Graham Land by making an

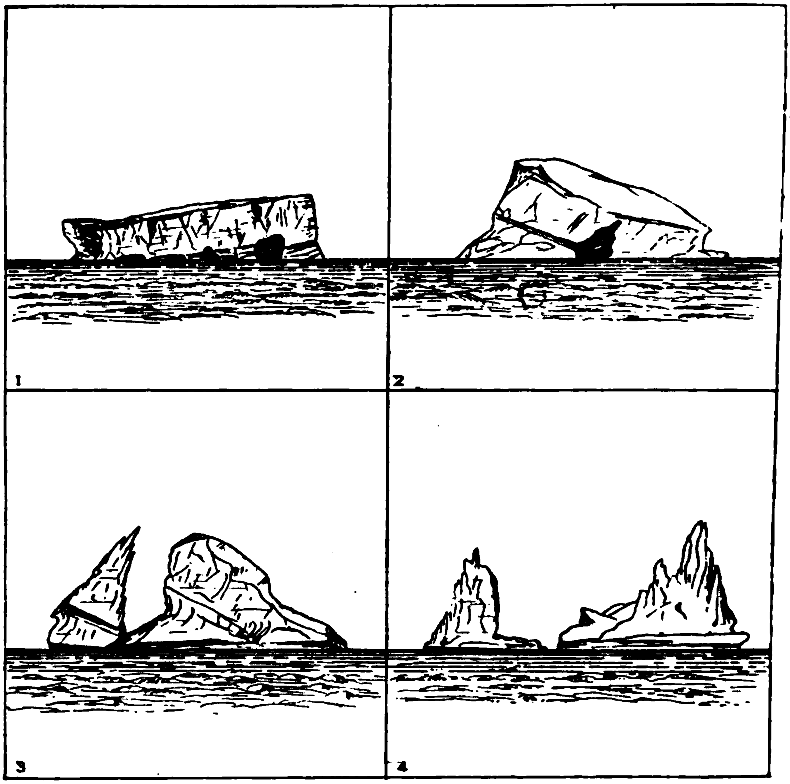


FIG. 14.—ANTARCTIC ICEBERGS, SHOWING TRANSITIONAL FORMS.

error of one degree in each co-ordinate; thus Pitt island is shown in 65° 20′ S. and 65° 40′ W., while Biscoe gave its position* as 66° 20′ S. and 66° 38′ W.

On Tuesday, February 15, continuing her south-westerly course, the *Belgica* crossed the Antarctic circle. During Wednesday, February 16,

* *Journal Royal Geographical Society*, February 11, 1833. The position as given in Biscoe's MS. log-book is, however, 65° 20′ S. and 66° 38′ W.

we tried to approach Alexander Land, which, however, proved to be inaccessible on account of the pack. At a distance of at least 20 miles from the land we obtained a sounding of 74 fathoms, with a rocky bottom, doubtless the shoal formed by the destruction of some former island by marine and glacial erosion. In the evening the sky became quite clear, and we were able to see a large island in the east, and the extremity of Alexander Land. The island seemed to mark the termination of Graham Land, for the coast beyond it seemed to turn towards the east. It may be, therefore, that there is a strait, or at least a gulf, between the two lands. We could not say positively that we saw the south coast of Graham Land, because the distance was too great. The island formed a mountain chain with many valleys entirely filled with glaciers, but the forms of the mountains were not those of the north. I saw no sharp crests; there were rather great pyramidal masses, their lower slopes having the appearance of terraces—no doubt, hills buried in snow. All round the island a great plain of ice sloped outwards, and merged into the surrounding pack. Alexander Land, in the south, was a mountainous aggregate over which very lofty peaks rose majestically; it tended north and south, and was lost to view vaguely on the horizon. A cape was seen in the north of this land, which formed the extremity of an east-and-west chain, though how far it ran to the east we could not see, nor could we be sure that it did not terminate in a great mountainous mass which rose beyond it, and of which the chain might only be a branch. In fact, two or three other lines of mountains seemed to run parallel to each other, unless, indeed, these lines are only those of important valleys; anyhow, there is a great mass of high land in the south-east. Towards the south the mountains seem to become lower and of more gentle outline. It is worthy of notice that here also a plain of ice of gentle slope lies at the base of the mountains, the glaciers merging into it from above, the plain itself merging into the sea-ice studded with imprisoned icebergs. In Alexander Land the glaciers thus fail to reach the sea, for they coalesce together into one great ice-foot, the existence of which fully explains the numerous tabular bergs which we encountered during the last two days. The great difference in the configuration of Alexander Land and the land we had seen further north may very probably be accounted for by the fact that Alexander Land lies outside the region of subsidence. Alexander Land has a wider basis than the Palmer archipelago or the northern part of Graham Land; it possesses a continuous coast-line in place of mountains, plunging perpendicularly into the sea. The continuous coast-line seen from a distance may indeed be broken into bays and capes in detail, but, even if so, all these irregularities are buried under the uniform plain of the ice-foot. But, on the other hand, we do not know what the scenery of the lands discovered by the *Belgica* would be like if they were restored

to their aspect of the glacial epoch under a burden of ice as heavy as that which bears upon the remote Antarctic solitudes of Alexander Land.*

* There is a very noticeable difference between my description of Alexander Land and that given by Dr. Cook in his work, 'Through the First Antarctic Night.' I cannot discuss the question from memory, and the only thing that I can say is that all my notes were written on the spot from day to day; that I have always made a point of giving correct descriptions and noting down exactly my first impressions. Cook says in his book that Alexander Land forms a group of islands, the largest of which is about 18 miles long, and that the mountains of this island attain a height of at least 4500 feet, etc. . . . It is always very agreeable to be able to furnish measurements, but when these measurements are simply based on estimate they do harm. It may be that the length of coast-line visible towards the south was 36 miles, and it is not improbable that the summits of Alexander Land reach a height of 9000 feet, or even more. The fact is that we made no measurements, and that we have little to add to the description as given by Bellingshausen.

TOPOGRAPHY OF SOUTH VICTORIA LAND (ANTARCTIC).*

By LOUIS BERNACCHI.

THE conception of a great *terra Australis incognita* has been proved to be equally erroneous with the conjecture that no land whatever, or of only trifling extent, was to be found. It has been proved that extensive masses of land exist within the antarctic circle; but whether the land takes the form of a vast continent, or an archipelago of islands smothered under an overload of frozen snow which conceals their insularity, or islands whose shores are washed by the ocean, remains still an enigma, and a fascinating one to be solved by future expeditions. It is, I think, premature to call it "the Antarctic Continent," for explorations on the American side, and even on that of Australia, tend to prove the existence of a broken-up continuation of these two continents with the most extensive masses of land lying under their respective meridians.

The coasts of Wilkes Land and the Balleny islands appear to be a duplicate of the Australian coast, so the gigantic mountain range to which the coast of South Victoria Land rises seems to correspond to the mountain chain of New Zealand; while the volcanic extremity of the cordilleras of South America finds its counterpart in the broken and scattered island masses also bearing volcanoes to the south of Cape Horn. The prolongation of the volcanic ring, or "circle of fire," from New Zealand to Balleny islands, South Victoria Land, and right across to the American side, seems to support this theory. Prof. Arçtowski, of the *Belgica* Expedition, has suggested that "Graham Land is connected with Patagonia by a submarine ridge, which forms a great arc extending between Cape Horn and the South Shetland islands, and that the tertiary chain of the Andes reappears in Graham Land."

Although, perhaps, the explorations of the *Southern Cross* have not thrown much light on this matter, the great mass of geological specimens collected might, if properly dealt with, assist very materially in arriving at a better knowledge of the conditions of things. The ship *Southern Cross* of the Newnes Expedition entered the antarctic ice-pack on the last day of the year 1898, and was nearly fifty days before penetrating to the ocean beyond, during which time she thrice crossed

* Read at the Royal Geographical Society, March 18, 1901.

and recrossed the antarctic circle. This, with the exception of the *Belgica,* is the longest period a ship has ever been involved in that pack. Our long imprisonment was due to having entered it so far west, in long. 158° 53' E., where it is very dense and heavy.

On first entering, ice was visible to the horizon in the south and west, whilst in the east and south-east there was open water. Our experiences, and those of other expeditions, tend to prove that the ice-pack on the Australian side of the antarctic circle is not nearly so dense in an easterly as it is in a westerly direction. Ships that have entered the pack in about 170° E. long. have penetrated it in a few days, whilst those entering it between 150° and 165° E. have taken more than a month. There are numerous instances in the history of antarctic navigation which go to prove this. A strong cold surface current appears to set out from Ross sea in a north-westerly direction, driving the ice up northwards, between Kerguelen island and Australia. At Cape Adare huge bergs were often observed, during perfectly calm weather, travelling at about 4 knots an hour towards the north-west. The prevailing south-east winds are also a factor in driving the ice in that direction.

The sea-ice, which constitutes the bulk of the pack, is first formed by the freezing of the sea in the winter along the shores of the antarctic lands. This freezes to an average depth of from 4 to 5 feet, and extends out into the ocean for perhaps 50 miles, until the formation of an uninterrupted sheet of ice is prevented by its perpetual violent agitation. This ice begins to break up early in November, and move northwards, and by the middle of January the coasts are almost free. As this body of sea-ice moves towards the north, it is frequently driven back by northerly winds. Thus, in consequence of the circumstance that land lies to the south, which excludes the possibility of more sea-ice following in support, an open sea, comparatively free from ice, is met with in the antarctic regions almost regularly when the principal zone of pack-ice has been pierced. Serious danger from ice-pressure in the open pack is comparatively slight. Once, on January 24, a rather severe pressure set in during a gale from the E.S.E., when the *Southern Cross* was fast wedged in the ice. On the port side the blocks piled up to a height of nearly 15 feet, and on that side the ship was lifted 4 feet out of the water, but at no time were we anxious for her safety. The pack, very susceptible to a gale, drives before it, and so there is really no danger, for there is no resisting force. But woe betide a ship that ventures to winter near the coast, unless it be a well-sheltered inlet, for when a pressure sets in there, it piles the huge blocks of ice up on the shore to from 20 to 60 feet, and a ship would surely be crushed, no matter how strongly she may be built. A real source of danger, however, is a gale or a very heavy swell on the edge of the pack, when huge masses of ice crash into the sides of the ship with terrific force,

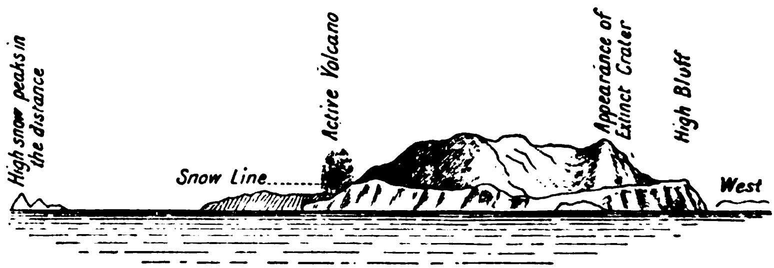
causing the tall masts to quiver for some seconds after the shocks, or the mighty blocks grind in against the sides as they pass.

At noon on January 12, a faint grey light was sighted on the port bow. At one time it looked like a cloud, at another it had the appearance of land. Finally it proved to be land, and very high land too. Our latitude at the time was 65° 3′ S., and longitude 161° 43′ E., the land bearing S. 20° E. true, distant about 70 miles. The day was beautifully clear, and not a breath of air stirred a ripple on the glassy patches of water. The land was at first taken by the captain to be some undiscovered island. I went up into the crow's-nest to have a better look-out; the captain was there in a great state of excitement, so convinced was he that he had discovered new land. Most of us, however, were extremely sceptical and could not participate in his elation. It seemed improbable that such an able navigator as Sir James Ross, who actually went over the same ground, should have missed this discovery. When we perceived a dull volume of smoke rising from the east end of the land, undoubtedly the smoke of a volcano in activity, we decided it was one of the Balleny islands upon which Balleny mentions the presence of an active volcano. As we approached closer, the outline of the land became admirably clear and defined.

Owing to the abundance of light reflected from the white, glittering snow-clad surface, few shadows were cast on any part. Observed through the telescope, abundant detail could be made out. A vast mantle of snow descended to within 600 or 800 feet of the sea, and there ended abruptly. On account of the great refraction and the very sharp contrast between the immaculate white of the snow and the jet-black of the cliffs, this snow-line was easily traced right along the land even with the naked eye. From the appearance of its edge, the snow-cap must have been some hundreds of feet thick. At the west extremity was a high truncated headland, and above this headland to the east was a peak some 10,000 feet high, with a large and apparently inactive crater at its summit. At the east end the land was comparatively low, and, from its blue appearance, at a great distance from us. It was from this part that the dark volumes of smoke issued at intervals. Low down in the eastern horizon were snow-clad pinnacles, only discernible by the aid of the telescope. Outwardly the land exhibited a naked, desolate appearance, a volcanic desert, covered with ice and snow, and so surrounded with ice ejected from the glaciers and forced on to the shores by the north-west current, that it is difficult, if not impossible, to examine the coast very closely. We approached to within 40 miles of the land, and then progress was completely stopped by huge blocks of ice, which had evidently only quite recently rolled down from the lofty peaks. We moored to a floe, and decided to wait until the ice opened up, and so allow the ship to approach closer to the shore. Plans were made for landing the next

day, if possible, and it was intended to send a short sledge expedition into the interior to investigate the country. But the next day a gale arose, and the ship was compelled to steer northwards to more open water, as it was dangerous to remain in the vicinity of such heavy ice. A dense fog hung over the sea, completely blotting the land from sight; and so, as there appeared but little possibility of making land in that kind of weather, and there being no likelihood of it clearing, it was decided to abandon the idea and to proceed on our way to Cape Adare. Thus all our nicely arranged plans made the day before were frustrated.

Towards the evening of January 28, the clouds, which for days had persistently obscured our horizon, lifted and disclosed to our eyes the rugged outline of a mountainous land to the south. Nothing could look more inhospitable. At this time (10 p.m.) the east extremity



ONE OF THE BALLENY ISLANDS, LAT. (OF SHIP) 65° 3′ S., LONG. 161° 43′ E. CENTRE OF ISLAND BEARING S. 20° E. TRUE, DISTANT ABOUT 50 MILES.

was bearing S. 26° E. true, and the west extremity S. 45° W. true. Our latitude at noon was 66° 46′ S., long. 165° 40′ E., and variation of compass 30° E.; the land at that time being distant about 40 miles. There is little doubt that the land we sighted was one of the Russel islands discovered by Sir James Ross in 1841. It has been suggested that the Balleny islands and the islands seen by Ross near them were identical. We have proved that they were groups quite apart. The Balleny islands were discovered on February 9, 1839, and consisted of three islands. The west cape of the middle island lay in lat. 66° 44′ S. and long. 163° 11′ E. Buckle island was in active eruption in two places when Balleny saw it. To the east of it lies Sturge island, which is cone shaped, whilst Young island is the largest and highest of the group. Ross's discovery lies more to the south-east. The position of Russel Peak, according to Ross, was lat. 67° 28′ S. and long. 165° 30′ E., with which our observations agree. Those observations were very carefully taken in an artificial mercury horizon, placed on the surface of a large icefloe, by Lieut. Colbeck and myself. I have mentioned this in justice to Lieut. Colbeck, whose observations have evidently been miscopied from his original observation book, and

have appeared in the recent publication, 'First on the Antarctic Continent,' in a somewhat quaint and unusual form.

The following day being fine, the land was plainly visible. It was not more than 40 miles from us, and was covered with vast piles of snow which never melts, and seems destined to last as long as the world holds together. At the east end of the island a high cape fell perpendicularly into the sea. The west end sloped up gradually from the water's edge to a lofty peak (Russel peak), which, as far as could be estimated, was 10,000 feet high, and, where not covered with snow, terminated in sharp and jagged ridges of a very dark colour. The whole range was of a serrated nature, and the snow-cap extended to the water's edge, whereas on the land we had sighted a few days back it did not. The whole of the north side presented to our view was precipitous, and in some places cliffs between 500 and 1000 feet high fell sheer into the sea; it would have been vain to attempt a landing.

On February 17, Cape Adare (lat. 71° 18′ S.) was reached, a cape of a very dark basaltic appearance, with scarcely any snow lying upon it, thus forming a strong contrast to the rest of the snow-covered coast. This lack of snow is principally due to the very exposed position of the cape to the south-east winds, and perhaps also to the steep and smooth nature of its sides, which afford no hold for any snowfall. The most striking features of this new world were its stillness and deadness, and impassibility. No token of vitality anywhere; nothing to be seen on the steep sides of the mountains but rock and ice. Here and there enormous glaciers fell into the sea, the extremities of some many miles in width. Afterwards, when the mist had cleared away, more than a dozen were counted around Robertson bay. As we approached, the sounding-line was kept going, but there was deep water close in to the shore. Indeed, there is little danger of finding banks or outlying submerged rocks anywhere along the coast of South Victoria Land. The "Dunraven rocks," indicated on Ross's chart as lying off Cape Adare, and over which, Ross states, the seas were breaking when he observed them, apparently do not exist; for, although a most careful search was made for them during the twelve months we were at Cape Adare, they were never seen. If they exist, they could not have failed to betray their presence during boisterous weather. Could it have been a large rotten submerged mass of ice that Ross mistook for rocks? With the exception of one place where a pebbly bank could be seen, basaltic cliffs rose sheer out of the water to an average height of about 500 feet.

The place upon which we had landed was a triangular-shaped and undulating bank or platform of detritus, the centre of which was about 20 feet above the water-level, and the whole area some 180 acres. It was formed of rounded boulders, pebbles, gravel, and, near the mountain-side, angular masses of *débris*. How this bank first came to be formed is difficult to determine for one who is no geologist; possibly it is the

result of glacier action of some kind, or is simply a raised beach. Many stones, however, are blown down from the summit of the cape by the furious winds which sweep over those regions all the year round. The alternate expansion and contraction caused by seasonal and rapid daily changes in temperature is the principal cause in disintegrating the cliffs. The vicissitudes in temperature during the year, more especially during the winter, are at times extreme and astonishing. We have witnessed, in the middle of winter, the temperature alter in a few hours from $-35°$ Fahr. to $+25°$ Fahr. Ice forming in the cavities of the rocks, at a few degrees below the freezing-point, exerts an enormous disruptive force. The volcanic rocks, being all porous, in the summer collect much moisture; when the temperature falls, they have their particles pushed asunder by the freezing of the interstitial water. The observed amount of destruction thus caused is enormous; large blocks of stone are split off and launched to the base of the declivities. Some measure of its magnitude in those regions may be seen in the heaps of angular rubbish at the foot of the crags and steep slopes all along the coast. There are many places where soil might form if it were not for the action of the winds, which blow all the finer disintegrated particles into the sea. The winds, blowing with cyclonic force, are so strong that loose rocks on the face of the cliff are hurled down, and blocks of stone and loose gravel swept away. Gravel and pebbles were heaped up in mounds and ridges. In some places these ridges coalesced so as to enclose basin-shaped hollows, that were filled with strong-smelling liquid matter, which, in the winter, froze solid. Some of these hollows were more than 100 yards in diameter. Bleached remains of thousands of penguins were scattered all over the platform, mostly young birds that had succumbed to the severity of climate. Thousands of years hence, if the species should become extinct, those remains, frozen and buried among the *débris*, will be available as a proof of what once existed in those gelid regions, now just habitable, then, perhaps, not at all. That same night Mr. Evans and I climbed to the summit of Cape Adare (850 feet by aneroid). By following a ridge of craggy rocks we found the climbing tolerably easy, and reached the top in less than an hour. The scene before us looked inexpressibly desolate. A more barren desert can scarcely be conceived, but one of immense interest from a geological point of view. From the end of the cape to the foot of the mountain beyond, a great waste of hollows and ridges lay before our eyes—ridges rising beyond ridges like ocean waves whose tumult had been suddenly frozen into stone. Beds of snow and ice filled up some of these extensive hollows, which had been scooped out by glacier action. Innumerable large erratic boulders lay scattered about, which had, no doubt, been transported to their present positions by the ice-sheets from places many miles away. One huge boulder, which rested on the outer edge of a great basin

scooped out of the volcanic rock, was of grey granite, and about 10 feet in girth; some other boulders were of a green formation resembling diorite. In the eroded beds, and among the *débris*, we found numerous pieces of quartz with bluish streaks running through them. I was especially struck by its resemblance to some auriferous quartz met with in Australia. We also picked up pieces of pink and red granite, and a hard greyish stone of the consistency of flint.

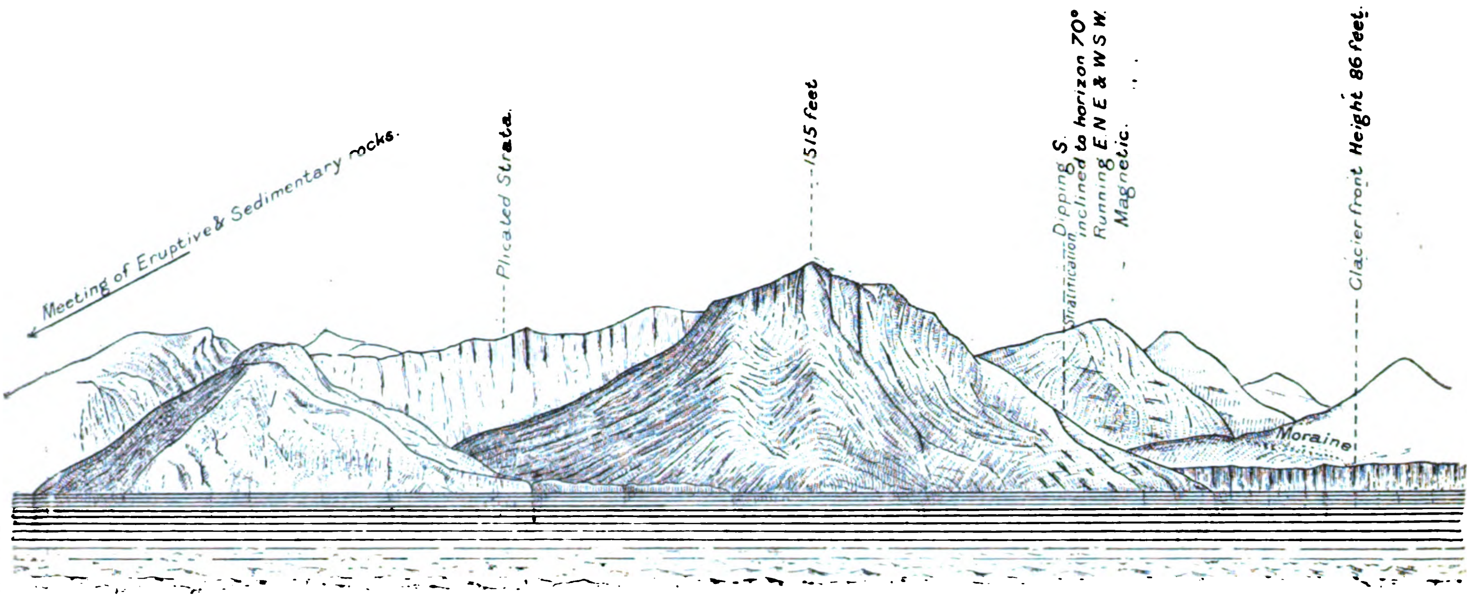
I wish to refer here to a statement made after the return from the south polar seas of the whaling ship *Antarctic* in 1895, to the effect that "the intercalation of lava and ice had been observed at Cape Adare, and that in one place the lava-flow appeared quite fresh." This statement has been very widely accepted as authentic. Sir Archibald Geikie has referred to it in numerous geological papers, more especially in his address before the Antarctic Congress in 1898. Dr. Karl Fricker also makes mention of it in his work on the antarctic regions. Unfortunately, the statement is absolutely without foundation, for there is no sign of the intercalation of lava and ice in the old eruptive formation at Cape Adare, nor anywhere else along the coasts of South Victoria Land, unless it be in the vicinity of Mount Erebus.

As we are dealing here exclusively with the topography of the antarctic lands, I will pass over everything which is not related to the subject. On August 14, 1899, a sledge party set out from the hut at Cape Adare for the purpose of exploring the southern extremity of Robertson bay. No doubt it would have proved more valuable and interesting to have investigated the shore-line in the direction of Smith's inlet and Cape North, and examined closely the whole contour, which might have yielded geographical and geological discoveries of much value. Besides this, the accurate astronomical positions of headlands, inlets, glaciers, etc., could have been laid down, and soundings taken through the numerous open seal-holes. We reached what we thought to be our destination very late at night, and camped between two walls of ice. These walls of ice puzzled us considerably, and it was not until the following morning, when we had climbed to the summit of one of these barriers and were able to get a view of our surroundings, that we discovered we had steered a wrong course during the previous night, and, in the darkness, had run into a kind of inlet between two huge tongues of ice 5 or 6 miles further down the coast—a veritable *cul-de-sac*. These tongues of ice, which were the seaward prolongation of two great rivers of compact crystalline ice creeping down from the deep mantle of snow and ice enveloping that polar land, extended out into the bay for a distance of 3 miles, and were, perhaps, half a mile broad. Two glaciers traversing convergent valleys united at a point about 6 miles above one of these tongues, and the lateral moraine stuff, which could be easily traced on one side of each, coalesced and formed a broad and conspicuous medial moraine down the centre. Much of the moraine

rubbish, however, was concealed by the loose snow on the surface. I measured the height of the ice-ramparts in several places by carefully marking out a base-line on the frozen surface of the sea, and observing the angles of elevation with the sextant; the average height was about 90 feet. Of course the icebergs formed in Robertson bay do not attain anything like the dimensions of those drifting up from farther south, where the glaciation is so much greater. On the lee side of the ice-tongues great piles of snow-drift were accumulated by the east-south-east winds, and heaped up almost on a level with the summit of the wall. The sea-ice around the extremities of the tongues was very little cracked or crushed together, thus indicating that the movement of the glaciers was not, at that time of the year, very considerable.

The glaciers of the antarctic do not, I think, move rapidly at any time of the year. In this respect they are very different to those of Greenland, some of which, I believe, are the most rapid moving glaciers on the surface of the globe. No actual measurements on the rate of motion of the glaciers of South Victoria Land have been made, so that nothing positive respecting them can be advanced. Sharp detonations, however, were frequently heard, showing that there was some movement going on in the mass.

The spot where we ultimately camped was a small islet, which has been named Duke of York island, and which is, perhaps, 3 miles in circumference, and surrounded by a glacier that nearly conceals its insularity. The geological formation consists of a greenish slatey rock of very fissile structure, which is on the whole intensely crumpled and plicated. Crystals of pyrites occurred disseminated throughout the formation, in some places in great abundance. The pyrites appeared in small cubical perfectly opaque crystals, which, with reflected light, showed the characteristic brassy lustre of the mineral. These crystals appeared to yield but slowly to weathering, for generally the cubical crystal could be seen projecting still fresh from the stone, which had no doubt been long exposed to the atmosphere, and a small blow would, in many cases, loosen the entire crystal from the rock. The formation was here and there traversed by thick veins and narrow threads of quartz, showing strong evidence of disturbance, and seemed to have been exposed to a powerful lateral pressure; this quartz contained bluish and rusty-coloured streaks. In the crevices of the slate rock a dark soft soapy substance something like graphite was found. In some places the stratification formed roads on the side of the mountain some 30 or 40 feet in width; in other places the greenish colour of the formation was changed to a dull brick-red, as if it had been under the influence of heat. Whether this is really caused by heat or is merely the ordinary effect of weathering, I do not know; I think the latter cause is the most probable. These red patches were ·icuous some miles away, and were exactly similar to the formation



SKETCH OF LOCALITY IN SOUTH END OF ROBERTSON BAY, WHERE SLATE FORMATION BEGINS.

around them, and, relatively, in no way disturbed. The slatey formation extended as far north along the coast as we examined, which was about 5 miles, the general inclination of the stratification being about 60°, and dipping south. How interesting, from a geological point, it would have been to follow the formation round towards Cape North!

At a place about 2 miles south of the islet, and right in the bottom of Robertson bay, a dark eruptive rock of very great density and very hard flowed over the sedimentary formation, and thus completely hid from view its southern prolongation. It probably continues underneath the lava-flows towards Mount Erebus. At Wood bay it will probably be found outcropping again on the surface. This sedimentary formation is of immense interest; it appears to continue north towards Wilkes Land, for Dumont D'Urville found slate rock at the place where he landed in the neighbourhood of "Pointe Géologie," and it possibly underlies most of the volcanic rock of the antarctic lands. This slate formation also appears among the islands south of Cape Horn. The geology of the antarctic is a subject replete with interest for the connoisseur. In the extensive sedimentary deposits fossils might be found with indications of a warmer climate during some former epoch.

An attempt made at this time to cross the mountain range was unsuccessful. Indeed, it became evident, soon after our landing at Cape Adare, that any attempt to penetrate far into the interior would be futile, owing to the rugged and precipitous nature of the mountains which had to be crossed before reaching the inland ice visible beyond. The Admiralty range of mountains in Robertson bay is the most formidable range in South Victoria Land. Rising to an average height of about 7000 feet, and partly free of snow on its northern slopes, it presents an impassable barrier to a sledge-party. The greatest altitude we succeeded in reaching was 5200 feet, a little to the south of Cape Adare.

On January 28, 1900, the *Southern Cross* returned to Cape Adare, and on February 2 we were all on board and steaming southwards along the coast. The coast-line from Cape Adare to Cape Downshire is exactly similar to that of the north shore of Robertson bay; the same igneous formation, with precipitous cliffs, and here and there pillars of rock standing out a short distance from the shore.

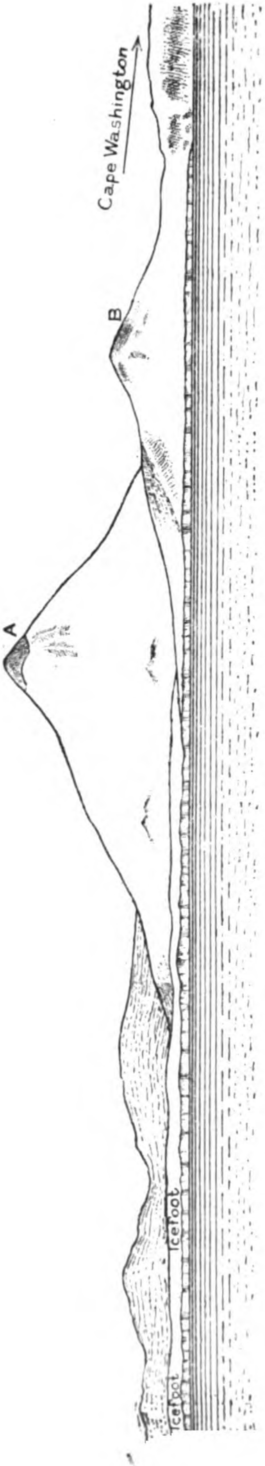
Early on the following morning a landing was effected on a rough pebbly beach on the western side of Possession island. This island, which is the largest of a small group, is low—the highest part, a peculiar abrupt bluff on the south side, being about 300 feet high. It is almost entirely covered with a snow-cap averaging from 1 foot to 20 feet in thickness, and the whole island is, I should say, about 4 miles in circumference. Many large rocks were observed to the south of the larger island, two being basaltic pillars rising sheer out of the sea and attaining a height of about 100 feet. In another rock the sea had perforated three arches, one so large as to almost admit the passage of

the ship. Towards noon we were off Cape Rogel. A large body of ice lay off it and at the mouth of Mowbray bay, so we were compelled to make a long *détour* towards the east to avoid it. In the afternoon Capes Christie, Cotter, and Hallet were passed, all bold rugged headlands of volcanic formation, and partly free of snow.

Coulman island was reached on the 4th. The shore on the western side looked so precipitous, that at first we entertained but little hope of effecting a landing. At one place a perpendicular cliff, some 1500 feet high, fell sheer into the sea; to the right and left were the walls of the ice-cap, about 100 feet high, and extending for some distance out into the sea. After some risky manœuvring in the surf, we succeeded in landing at a spot at the base of the cliff. There was, however, nothing to see except the walls of the cliff, the formation of which is volcanic and similar to that at Cape Adare. On the mainland, about 14 miles due west of Coulman island, we discovered a kind of inlet or arm running into the glacier for a distance of about 3 miles. This spot was well sheltered from winds, and from it the inland ice-cap was easily accessible; but it was scarcely safe for a ship, on account of the heavy ice-pack, which is borne by the current into the channel between Coulman island and the mainland.

At noon on February 6, Mount Melbourne was sighted to the west-south-west. We were all struck by its extraordinary resemblance to Mount Etna. Rising up gradually out of the sea to an altitude of nearly 8000 feet, with a canopy of cloud upon its peak, it presented an imposing sight. All afternoon we steamed down Wood bay, which runs much farther inland than indicated on Ross's chart; at the bottom of it there is a long inlet or fjord, affording a capital harbour. Late in the evening, we landed on a pebbly beach at the foot of Mount Melbourne. The place upon which we landed was a pebbly bank even larger in extent than that at Cape Adare, entirely free from snow and "ponds" and occupied by penguins and skua gulls. A better spot for winter quarters, I think it would be difficult, if not impossible, to find in those latitudes. It is the only place in South Victoria Land where a ship can winter with perfect security. From here there is quite an easy access to the great snow-cap, not more than 100 feet to climb, and a very gradual gradient. This part of the coast is actually the closest approach to the south magnetic pole, it lying in an almost westerly direction from Wood bay distant between 200 and 300 miles. I do not, however, wish to imply that observations can be taken in the vicinity of the magnetic pole without much difficulty, for it is quite within the bounds of possibility that an open sea may be encountered before reaching a distance of 200 miles in a true westerly direction—that is, if an archipelago of islands exists, instead of a vast continental area.

If a land party should winter near Mount Erebus and Terror, there



SOUTH SLOPE OF MOUNT MELBOURNE, SHOWING WHERE ICEFOOT, CONNECTED WITH MCMURDO BAY, BEGINS.

A, Mount Melbourne, 8000 feet high; B, Pyramidal Mount, 2000 feet.

is an easy way of communication between such a party and a ship wintering in Wood bay by means of an uninterrupted ice-foot, which, commencing from the southern slopes of Mount Melbourne, continues southwards as far as McMurdo bay. The surface of this ice-foot is perfectly level, covered with hard compact snow, and is but little crevassed, as was actually determined by two landings upon its surface in the vicinity of Cape Gauss, which is itself buried in the ice-sheet.

The distance between McMurdo bay and Wood bay is about 170 miles, which, with sledges and dogs, and such favourable conditions of ice-travelling, could be covered in eight days. The surface of this ice-foot is easily reached from Wood bay by going round the foot of Mount Melbourne from behind. The geological formation here was volcanic, but not compact or magnetic rock. It consisted mostly of scoriæ, no doubt ejected from Mount Melbourne, which, most probably, was at one time a volcano in activity. Some pieces of slate were seen on the beach, but, being engaged in taking magnetic observations, I had no time to search for any outcrop of this formation. The observed height of Mount Melbourne is 7200 feet. It is entirely snow-clad, and rises directly from the sea. The bare rocks at the foot of the mountain have weathered into many fantastic shapes.

On February 9, we landed without difficulty on the western side of Franklin island, on a pebbly bank similar to that in Wood bay and at Cape Adare. The whole island is of volcanic formation, one heavy greenish vitreous rock being especially interesting. From Franklin island we steered straight for Mount Terror, without approaching McMurdo bay, a close examination of which would have been of much value, for possibly there is a spot on its shores where a party might be able to winter; but the discovery of a sheltered inlet where a ship could safely winter is, I think, extremely improbable. On the 10th we

sighted Cape Crozier and Cape Bird and the foot of Mount Erebus and Terror, but the dense masses of clouds wholly obscured all but the immediate coast-line. At the foot of Mount Terror we lay to for some hours in the hope of getting a glimpse of the summit of Mount Erebus, and procuring a photograph. But as the pall of clouds showed no sign of breaking, we waited no longer, and steamed on towards Cape Crozier, which we passed a little before midnight. I must mention, however, that on the afternoon of the following day the mist lifted for a short time, and enabled us to see Mount Erebus from the deck. Smoke could be easily distinguished arising from its snow-clad summit, so that it was evidently not quiescent; but whether it was in a state of eruption, as at the time of the visit of Sir James Ross, we could not distinguish, being too far away. It was a most cursory and imperfect glance that we got, for the dense mist soon closed down again. The light was too bad and the distance too great to procure a photograph of the volcano.

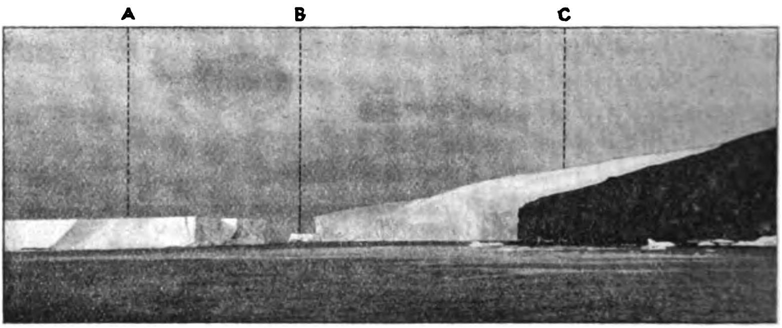
Soon after passing Cape Crozier, the mist rose from Mount Terror, and we obtained a fairly good view of it from base to summit. It is, of course, very lofty, but scarcely looks the height (10,884 feet) that Ross assigns to it. Strange to say, its eastern side was almost free from snow, and on the same side were numerous knolls, some having crater mouths, and which at one time were the monticules of the parent volcano, now apparently extinct. Even stranger than the absence of snow on Mount Terror was the presence of an exceedingly large penguin rookery at its foot. This rookery was occupied by millions of penguins, and was far and away larger than any we had previously seen.

The foot of Mount Terror is low, and at the spot occupied by the penguins there is a kind of miniature plateau upon which a party could possibly spend a winter, although, I believe, it would be an extremely severe one. One of the greatest difficulties, if not the greatest, would be the excessive cold to be contended with, for even in the middle of summer, with a wind from the south, the temperature sinks considerably below zero; thus, on February 19, with a light wind from the south, the temperature fell to $-12^{\circ}\cdot 5$ Fahr. What, then, must we expect in the depths of winter with the wind from the same direction?

After having passed Cape Crozier, Ross's great ice-barrier came in view, stretching away out of sight towards the east. Scarcely any natural feature of the antarctic world has so stirred the imagination and so roused scientific interest as the discovery of this great ice-barrier. The most surprising characteristics of the great ice-barrier are its unbroken uniformity, its vast extent, and the entire absence of visible land from its edge. Imagine a perpendicular wall of ice, from 100 to 200 feet high, suddenly rising up before you out of the ocean, where the depth of that ocean is measured by hundreds of fathoms, and hundreds of miles distant from any visible land, for you soon lose sight of Cape Crozier and Mount Terror. There are no breaks

in this wall, and it is very little water-worn, proving the rare occurrence of gales from the north and the accompanying high seas, which would otherwise wear huge caves into it; its summit affords absolutely no obstacle for travelling with sledges and dogs, being smooth and level and but little crevassed.

A theory has been advanced and very widely accepted that the great ice-barrier is the front of a huge polar ice-cap, which moves from the south pole northwards. It has even been calculated that the centre of this polar ice-cap must be 3 miles, and may be 12 miles deep, and that, the material of this ice-mass being viscous, its base must spread out under the crushing pressure of the weight of its centre, and the extrusive movement thus set up is supposed to thrust the ice-cliffs off the land at a considerable rate. The improbability of this theory is evident to any one who has carefully observed the barrier and the ice-caps of that part of



CAPE CROZIER, LAT. 77° 25′ S., LONG. 169° 10′ E.

A, iceberg; B, height nearly 200 feet; C, Crozier and the great ice-barrier.

the antarctic, none of which can possibly be more than 2000 feet in depth. The following theory with regard to the formation of the great ice-barrier I hope may bear logical scrutiny.

In the first place, reasoning from analogy, all the ice-sheets of South Victoria Land, due to the north and south trend of the lofty mountain ranges, flow towards the east, and the glaciers extend for long distances into the sea in the form of huge tongues of ice, their length varying according to the extent of glaciation due to differences of latitude. Thus, in Robertson bay (lat. 71° 18′ S.), some run out into the sea for a distance of 3 miles, and are half a mile in width; whilst near Cape Gauss (lat. 76° S.) they extend as far out as 30 miles, and are 4 or 5 miles across. These tongues of ice are characteristic of every glacier. Why should the great ice-barrier be an exception? The huge Parry range of mountains runs parallel with the coast, and appears to be simply a continuation of the coast-line, for there is absolutely no land in sight to the east of them. It follows that the ice-sheet, which covers these mountains and where the glaciation attains its maximum dimensions,

must flow eastwards in the same direction as it does a few miles to the north of them. If the ice flowed northwards from the south pole, the ice-barrier near Cape Crozier would extend out into the sea, just as do all the glaciers of South Victoria Land; but this is not so. The edge of the barrier is at least half a mile behind Cape Crozier. Again, the surface of the ice-sheet would gradually rise from the edge towards the south. It does not, but rises from the east towards the west. Then it is evident that the great ice-barrier moves from the west towards the east. Therefore it appears as if the great ice-barrier is nothing more than a huge tongue of ice flowing eastwards into the ocean for a distance of perhaps 500 miles, and is possibly not more than 50 miles in width; so that, if the party from the *Southern Cross*, that landed on the barrier in lat. 78° 34′ S. and long. 164° 32′ W., on February 17, 1900, had continued their journey farther south, they might have come to an open sea on the other side.

The heavy ice-pack met with near this spot tends to prove the existence of a considerable track of ocean to the south, whose frozen surface only breaks up late in the year and moves out and around the extremity of the great ice-tongue or barrier in the usual north-westerly direction. If an extensive land area were behind, or farther east, such a large mass of sea-ice would be impossible. Sir James Ross reported the "appearance of land to the south," near the spot where we landed on the barrier. We did not, however, sight any land, although we had exceptionally fine clear weather. I do not wish to imply that it does not exist, possibly it does, and is either an island or the eastern shore of a large deep bight extending from Mount Terror around towards Graham Land; but I do believe that there is an open sea between the southern side of the great ice-barrier and that land, if it exists.

There is one thing that appears to go against the above theory, and that is the comparatively shallow water found at the spot where we landed on the barrier, viz. 350 fathoms. But can we reasonably expect to find deep water near the south pole, where everything tends to prove the existence of an archipelago of large islands? The few indications which we possess of the depth of the ocean in this part of the world, seem to indicate that there is a gradual shoaling of the ocean from very deep water towards the antarctic lands. The ice-barrier in long. 164° W. is distinctly different in appearance to that observed further west. Its outlines were more broken and full of indentations; the elevation, too, was no more than 60 or 80 feet. The fact that the position of the ice-barrier where we landed upon it was found to be many miles further south than reported by Ross is possibly due to a large portion of the barrier having here broken off and drifted away in the form of huge icebergs. Or, again, Ross might not have approached the barrier very closely at this particular spot, his highest south point being 30 miles more to the east.

Before the reading of the paper, the PRESIDENT said: I think I can promise you a very interesting paper from Mr. Bernacchi. He is a young independent observer, and I think a very shrewd observer, and he has had the great advantage of observing in a most interesting part of the antarctic regions which has not previously been visited for nearly sixty years. I will ask Mr. Bernacchi to read his paper on the Topography of South Victoria Land.

After the reading of the paper, the PRESIDENT said: In introducing Mr. Bernacchi, I forgot to mention what I had promised to state, namely, that the reading of Mr. Bernacchi's paper had the full consent of his former chief, Mr. Borchgrevink. We hope that Sir Joseph Hooker may be disposed to make some remarks on the views expressed by Mr. Bernacchi.

Sir JOSEPH HOOKER: I have listened with very great pleasure to this most interesting and clear account of Mr. Bernacchi's of the phenomena that he has witnessed in the antarctic seas and lands. So far as my very vivid recollection carries me, they precisely agree with what I saw myself now upwards of sixty years ago, put in a very clear and most instructive manner. Of course, the great interest of the voyage and observations is that great ice-barrier. That ice-barrier, I think I may safely say, presents the most remarkable unsolved glacial problem in the world, and there has been really no satisfactory explanation given of it. That which Mr. Bernacchi has put forward, which he very wisely regards as a mere speculation, is a very ingenious one, and it may be a true one, but it is exceedingly difficult to conceive any amount of *névé* in the Parry mountains driving a body of ice of that dimension over 300 miles. It is practically a plane surface, and we know nothing like it in any other part of the world. Then, again, with regard to there being water on the southern slopes of this barrier, is it not a fact that on no occasion did Mr. Borchgrevink see anything like a water-blink in the sky in that direction? If there had been much water within any reasonable distance to the southward, I think we could not fail to perceive a water-blink in the sky. These are the only remarks I have to make.

The PRESIDENT: Mr. Bernacchi allows about 50 miles of width.

Sir JOSEPH HOOKER: Yes. I should like to ask Mr. Bernacchi if Mr. Borchgrevink's party saw any appearance of these mountains seen by Ross from the extreme eastern edge of the barrier?

Mr. BERNACCHI: No, none at all.

The PRESIDENT: Were you as far east as Ross?

Mr. BERNACCHI: No; within 30 miles of Ross.

Dr. BLANFORD: I have not had time to look at the geological specimens exhibited by Mr. Bernacchi; but the additional facts that have been obtained concerning sedimentary rocks and their resemblance to some of the Australian rocks are very interesting, and will lead to further identification. Of course, the most interesting fact about the antarctic land area is the probability that this at one time has formed part of either South America or Australia, or probably of both; because if it was not land at one time, and land which was not entirely covered with ice, it is very difficult to understand how some curious connections between the animal life of South America and Australia can have originated. The fact that one of the great groups into which the marsupials are divided is only represented in South America and Australia, is in itself extraordinary; and it appears, from some recent observations, that the number of South American forms allied to the Australian marsupials is much greater than we in past times supposed. Then another curious fact is with regard to the horned tortoise *Miolania*, of which remains have only been found in Australia and South America. There are other

points of connection in past times, and there is quite sufficient similarity between the faunas of the two areas to make it highly probable that at one time, when, perhaps, the southern hemisphere contained more land than it does at present, and the northern contained less, there was land union between South America and Australia. I think that the interest attaching to the glaciers and the ice-barrier is also a geological question. Just as one of the most important discoveries of the century was made when Nordenskiold penetrated into the interior of Greenland, so I think it is very probable that some equally important discoveries remain to be made when we know something of the interior of the antarctic land. Whether it is a continent or merely an archipelago of large islands, is one of the questions that remain to be solved in the antarctic area, and the exceedingly novel and interesting views which Mr. Bernacchi has brought before us about that enormous mass of ice throw an entirely new light upon the whole subject. The ice may be either the edge of a great glacier coming down from the land to the south; or it may be, as Mr. Bernacchi has suggested, a mass of glacier ice pushed out to sea, or it may be a mass of floating ice filling a sound between two large islands. It is very satisfactory to hear that it can be easily explored; and if it can be penetrated from 150 to 200 miles, it will at once be shown what its real nature is. If it is a glacier, the surface will rise rapidly towards the south; if it is a floating mass pushed off from the land, the surface will not rise rapidly, but will probably remain for a considerable distance very nearly at the same level.

Admiral Sir George Nares: With regard to Robertson bay, we are told of a remarkable double tongue of compact crystallized ice. Can Mr. Bernacchi tell us, was that likely to have been a summer river either at the spot or further back, and that it has been pushed forward by the glaciers?

Mr. Bernacchi: No, I do not think so.

Admiral Sir Leopold M'Clintock: May I ask the lecturer if he would kindly give us some information of the animal life to be found far south, as it is very important to know whether food could be obtained for men or dogs who might have to pass the winter there. You mentioned penguins, but I take it they only visit the coast in the summer season?

Sir Erasmus Ommanney: I should like to ask whether you made any exploration along the coast to the westward of Cape North, or did you see beyond that anything like the ice-barrier which was observed to the eastward? I presume the exploration of the coast was made under sea navigation, wasn't it?

Mr. Bernacchi: Yes, most of it.

Sir Erasmus Ommanney: Did you make any use of the dogs?

Mr. Bernacchi: Oh yes, in Robertson bay only. In reply to a remark of Sir Joseph Hooker with regard to the Parry mountains, I may say the snow-cap on the mountains is, I think, sufficient to force such a large mass of ice as the great ice-barrier towards the sea. We must remember that there are no slopes to the west of the mountain ranges in South Victoria Land, that there are only slopes to the east, and that there is a large body of snow and ice moving from the west right over the summits of the mountains, so that that would be quite sufficient to force a large mass of ice eastwards. Then, in reply to a question put by Admiral Sir Leopold M'Clintock, of course I am not very conversant with zoology or with animal life, but I can say there are no land animals to be found in South Victoria Land; but there are plenty of seals along the shore-line, both in summer time and winter, and they are always available as food for dogs and human beings, and the penguins, which can be procured during four months of the year, are also available as food for sledge-parties. And then I think Sir Erasmus Ommaney

asked a question with regard to explorations in the direction of Cape North. I am very sorry to say that no expeditions were undertaken towards Cape North. I do not know for what reason. The commander was requested to allow permission to undertake expeditions to Cape North by various members of his staff, but for some reason he did not grant that permission. There is no doubt we could have undertaken these expeditions, because the surface of the ice was not hummocky in that direction, and was perfectly secure, and remained so until late in December. And then with regard to an ice-barrier to the west of Cape North, of course I have not seen the barrier, and know absolutely nothing about it, but I believe the barrier was seen by Wilkes and Dumont d'Urville. In the first place, I think some of Wilkes' ice-barriers and lands are extremely improbable. Sir James Ross has proved that some of his lands did not exist, so also did the expedition of the *Challenger*. Of course Dumont d'Urville was more reliable, and there is no doubt there is an ice-barrier from Cape North westward, and I believe the length of it is about 90 miles. We can account for that in the same way as we can account for the great ice-barrier, for I believe most of the mountain ranges seen by Dumont d'Urville run north and south, not east and west, and appear to be a continuation of the Australian continent, for nearly all the mountain ranges in Australia and New Zealand run north and south. And then the same theory of the ice-tongue moving from the mountain slopes would apply to that ice-barrier, as it does to the great ice-barrier. Of course, there is no doubt that a very large field for exploration still remains in the antarctic regions, and the expeditions of the *Southern Cross* and the *Belgica* have not added very much to our actual geographical knowledge of these regions. The expeditions which are about to sail from England and Germany have a field for exploration greater than the whole of Australia, and the scientific results which would accrue from the exploration of so extensive and unknown a polar track must be very great; and surely we cannot boast of any brighter chaplet than that which has been gained in the field of scientific and geographical research. Explorations in the antarctic can have little commercial value, for a more barren spot could scarcely be conceived. As for gold—well, in the first place, you have got to find it, a most unenviable task, and you would fully deserve it if you were successful. But I do not think any rational-minded person would for a moment entertain so wild and picturesque an idea as that of discovering a second Eldorado in South Victoria Land.

The PRESIDENT: There were glittering stones, were there not?

Mr. BERNACCHI: Yes, but I don't think it was gold. Nor would the most ardent advocate of imperial expansion look to the territory surrounding Mounts Erebus and Terror as a sphere for his ideas.

The PRESIDENT: I think I may congratulate the meeting on having listened to an extremely interesting paper, and also an important paper from a geographical point of view. In the first place, the lecturer appears to have cleared up the question respecting the difference between Russel islands and Balleny islands. Then he has given us a clearer description of Robertson bay and Cape Adare and Duke of York island than we had previously received. His description of the excellent winter quarters in Wood bay is important. And it must be very gratifying to Mr. Bernacchi to find that his theory respecting the great ice-barrier has received the attention of Sir Joseph Hooker and Dr. Blanford, who have both expressed, at all events, their very great interest in it. I am sure you will all cordially pass a vote of thanks to Mr. Bernacchi for his very interesting paper.

ANTARCTIC BIBLIOGRAPHY.

? Bibliog. – Hist.
& Antarctic Regions.

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OF

ANTARCTIC EXPLORATION AND RESEARCH.

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THE basis of this Bibliography is the portion of the Subject Catalogue of the Library of the Royal Geographical Society dealing with the Antarctic Regions. Many important papers bearing on Antarctic exploration are not to be found in the Library, and an attempt has been made to render the Bibliography complete by referring to Chavanne's 'Literature of the Polar Regions' (No. 386), Baschin's annual 'Bibliotheca Geographica,' the geographical bibliographies in *Petermanns Mitteilungen*, and to other works of reference.

It was necessary to compile the Bibliography rapidly, and hence it was impossible to attempt to verify every title by reference to the original, or to hunt out a number of papers the existence of which was indicated somewhat uncertainly. Thus while we believe that no important book or paper dealing with the Antarctic Regions has escaped attention, we cannot say positively that all of minor importance are included. We believe that there must be narratives of the voyages of British and American whalers and sealers hidden away in many forgotten magazines and journals of local societies between the dates 1820 and 1840, the unearthing of which would cost much time and trouble.

In making the Bibliography as complete as it is, the compiler is indebted to his successor as librarian of the Royal Geographical Society, Mr. E. Heawood, and to Herr Otto Baschin, M. Henryk Arçtowski, M.

Racovitza, and other friends, who were kind enough to look through the proofs and suggest additions.

The arrangement is chronological with regard to the year of publication. In each year the works are arranged alphabetically under the authors' names; the comparatively few anonymous writings being placed at the end of each yearly list without any systematic arrangement.

A full index of the names of persons, and another of ships, mentioned in the titles have been added, so that when the date is unknown, many expeditions of which the name of the leaders or of the ships are known, although the dates are forgotten, may be readily found.

In the Bibliography no title of honour is, as a rule, prefixed to a name, and never one to which the person referred to was not entitled at the date of publication. In the Index, however, distinctive titles are prefixed to assist in fixing identity.

As it frequently happens that the account of a voyage is not published until long after it has taken place, a Chronological List of Antarctic Voyages has been drawn up in as concise a form as possible.

There has thus been produced for the first time a compendious index to the material available for the complete history of the Antarctic Regions up to the close of the nineteenth century, and the dawn of what may be confidently expected to prove an era of discovery far more important than any that has gone before.

CHRONOLOGICAL LIST OF ANTARCTIC VOYAGES FROM 1701 TO 1900.

1716. Le Gentil de la Barbinais reached 61° 30′ S.

1719. George Shelvoke reached 61° 30′ S.

1722. Jakob Roggeween reached 62° 30′ S., and one of his ships, the *Thienhoven*, is reported to have reached 64° 58′.

1738–39. Lozier Bouvet in the *Aigle* and Hay in the *Marie* discovered Cape Circumcision in 54° S., 4° E.; and went on to 57° S.

1756. The Spanish merchant ship *Leon* rediscovered South Georgia.

1771–72. Marion du Frezne and Crozet sailed from Cape of Good Hope to New Zealand, discovering Marion and Crozet islands.

1772. Yves Joseph de Kerguelen-Trémarec discovered Kerguelen Land.

1772–75. James Cook and Tobias Furneaux in H.M.SS. *Resolution* and *Adventure*, circumnavigated the world in as high a southern latitude as possible. The staff of the ships included, as scientific observers, Johann Reinhold Forster, his son Georg Forster, for part of the time the Swede Andrew Sparrmann and the English astronomers William Wales and William Bayley. The extreme points reached by the expedition were 67° 31′ S. in 142° 54′ W. and 71° 10′ S. in 106° 54′ W.

1773–74. Second voyage of KERGUELEN to Kerguelen Land, accompanied by D'AGELET LE PAUTE.

1808. JAMES LINDSAY in the *Snow Swan* and THOMAS HOPPER in the *Otter*, sent out by Messrs. ENDERBY, rediscovered Bouvet's islands.

1819. WILLIAM SMITH, while on a voyage from La Plata to Valparaiso, discovered the South Shetlands, and, on his return voyage, LIEUT. BRANSFIELD, R.N., accompanied him, and made a survey of the group.

1819. JAMES SHEFFIELD, on the American brig *Hersilia*, visited the South Shetlands on a sealing-trip; and for some years the neighbouring lands were regularly visited by British and American sealers, including WALKER, PALMER, PENDLETON, and POWELL.

1819–21. FABIAN GOTTLIEB BELLINGSHAUSEN, in command of the Russian man-of-war *Vostok*, and LAZAREFF, in command of the *Mirny*, visited South Georgia, and circumnavigated the Earth in a high latitude, reached 69° 21′ S. in 2° 15′ W., and 69° 53′ S. in 92° 19′ W., discovered Peter I. island and Alexander I. Land, and sailed over 46° of longitude within the Antarctic circle.

1822–24. JAMES WEDDELL in the brig *Jane*, accompanied by M. BRISBANE in the cutter *Beaufoy*, reached 74° 15′ S. in 34° 17′ W., and found open sea with almost no ice in sight.

1828–29. HENRY FOSTER in H.M.S. *Chanticleer* visited Deception Island in South Shetlands. The island was described by E. N. KENDALL.

1830 (?). EDMUND FANNING, with the American brigs *Seraph* and *Annawan*, visited the west coast of Graham Land.

1830–32. JOHN BISCOE, in the brig *Tula*, accompanied by the cutter *Lively*, sighted land in 66° 2′ S., 48° 54′ E., and also in 67° 15′ S., 68° 20′ W.; making a circumnavigation in high latitudes.

1832–33. LIEUT. REA, R.N., with two of the Enderby's ships, set out to continue Biscoe's researches, but the expedition did not get beyond the South Shetlands.

1833. LIEUT. BRINSTEAD, R.N., with the schooner *Hopewell* and the cutter *Rose*, fitted out by the Enderbys with the co-operation of the British Admiralty, sighted land between 65° and 70° S., in 10°–20° W. (?).

1833. KEMP, a sealer, found land in 66° S., 59° 30′ E.

1838–39. JOHN BALLENY, in the schooner *Eliza Scott*, with H. FREEMAN in the cutter *Sabrina*, were sent out by the Enderbys, reached 69° S. in 172° 11′ E., and discovered the Balleny islands and other land.

1837–40. J. DUMONT D'URVILLE, in the French corvette *Astrolabe*, and JACQUINOT in the *Zelée*, explored the Weddell sea region, and also discovered Adélie Land and the Clarie coast.

1838–40. CHARLES WILKES, in command of a U.S. squadron, consisting of the *Vincennes*, *Porpoise*, *Seagull*, *Peacock*, and *Flying Fish*, explored to the south and west of Palmer Land, and reported Wilkes' Termination Land south of the Indian ocean.

1839–41. JAMES CLARK ROSS and FRANCIS CROZIER, in H.M.SS. *Erebus* and *Terror*, discovered Victoria Land, circumnavigated in high latitudes, and reached a farthest south of 78° 10′ S. in 161° 27′ W., and in Weddell sea reached 71° 30′ S. in 15° W. ROBERT MCCORMICK and JOSEPH DALTON HOOKER were on board as surgeons and naturalists.

1842. WILLIAM G. SMILEY, American sealer, visited Deception island, and sailed round Palmer Land.

1845. J. L. MOORE in the *Pagoda* reached 67° 51′ S. in 39° 40′ on a special magnetic survey.

1873–74. DALLMANN in the whaler *Grönland*, sent out by a German company, visited Palmer Land and discovered the entrance to Bismarck strait.

1874. SIR GEORGE NARES, in H.M.S. *Challenger*, first crossed the Antarctic circle by steam, and reached 66° 40′ in 78° 30′ E.

1892–93. The Dundee Whaling Fleet, consisting of the *Balaena* (FAIRWEATHER), *Active* (ROBERTSON), *Diana* (DAVIDSON), and the *Polar Star*, visited Louis Philippe Land. Scientific observations were made by WILLIAM S. BRUCE and CHARLES W. DONALD, and paintings by W. G. BURN MURDOCH.

1892–93. LEONARD LARSEN, in the Norwegian whaler *Jason*, sent out by a German company, visited Louis Philippe Land and the Weddell sea.

1893–94. LEONARD LARSEN in the *Jason* reached 68° 10′ S. in 59° 59′ W. on the east coast of Graham Land.

1893–94. EVENSEN in the *Hertha*, and PEDERSEN in the *Castor*, sailed along the west side of Graham Land, Evensen reaching 69° 10′ S. in 76° 12′ W.

1894–95. LEONARD KRISTENSEN, in the Norwegian whaler *Antarctic*, with C. E. BORCHGREVINK on board, revisited Victoria Land and landed at Cape Adare and on Possession Island.

1897–99. ADRIEN DE GERLACHE, in the *Belgica*, discovered and surveyed Belgica strait, and drifted for a year in the ice to the west of Graham Land, reaching 71° 36′ S. in 87° 39′ W., and spending the first winter in the Antarctic Regions. LECOINTE, ARÇTOWSKI, RACOVITZA, and F. A. COOK took part in the expedition.

1898–99. CARL CHUN, on the *Valdivia*, rediscovered Bouvet island, and reached 64° 15′ S. in 54° 20′ E., although in an unprotected steel vessel. GERHARD SCHOTT was the oceanographer of the expedition.

1898–1900. CARSTENS EGEBERG BORCHGREVINK, in the *Southern Cross*, fitted out by SIR GEORGE NEWNES, landed and wintered at Cape Adare. He landed on the southern ice-barrier, and reached 78° 50′ in 165° W. LOUIS BERNACCHI and WILLIAM COLBECK took part in the expedition, with CAPTAIN JENSEN as sailing master.

ABBREVIATIONS USED IN THE BIBLIOGRAPHY.

THE system of abbreviations is that introduced in the *Geographical Journal*, and now employed with little modification in the geographical publications of all countries.

A. = Academy, Académie, Accademia, Akademie.
Abh. or Abhand. = Abhandlungen.
Ann. = Annals, Annales, Annalen.
B. = Bulletin, Bollettino, Boletim.
C. = Congress.
C. Rd. = Comptes Rendus (if alone, it refers to the Paris Academy of Sciences).
Erdk. = Erdkunde.
G. = Geography, Geographie, Geografia, Geographical, etc.
Ges. = Gesellschaft.
I. = Institute, Institution, Instituto.
Imp. = Imperial.
Iz. = Izvestiya.
J. = Journal.
k. u. k. = kaiserlich und königlich.
M. = Mitteilungen.
Mag. = Magazine.
Mem. = Memoirs, Mémoires.
Met. = Meteorological, Meteorology.
P. = Proceedings.
R. = Royal, royale.
Rev. = Review, Revue.
S. = Society, Société, Selskab.
T. = Transactions.
V. = Verein.
Verh. = Verhandlungen.
W. = Wissenschaft.
Z. = Zeitschrift.
Zap. = Zapiski.

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NAMES OF AUTHORS AND EXPLORERS.

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INDEX OF SHIPS' NAMES.

THE END.

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